AECOM Environment

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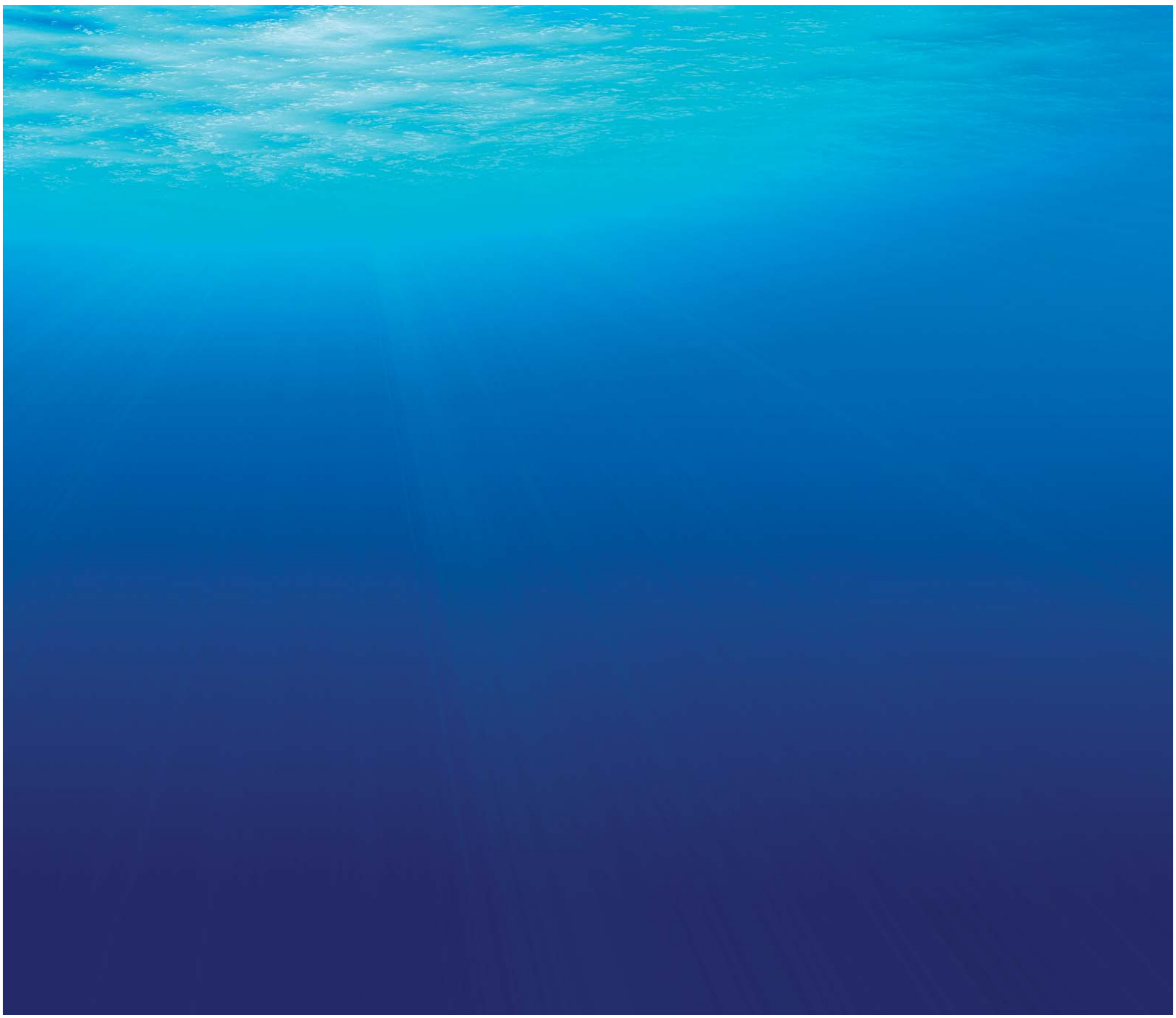
Water Level Monitoring in Three OPCJ Wells, Edina – St. Louis Park, Minnesota Final Report



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March 31, 2010

Mr. Nile Fellows
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Subject: Water Level Monitoring in Three OPCJ Wells, Edina – St. Louis Park, MN, Final Report. AECOM Project No. 60137283, MPCA Work Order SFST1010. The final report was completed under a different AECOM Project No. 60145589, Task 3.1.2, MPCA Work Order SFST1017.

Dear Mr. Fellows:

We are pleased to present this report "Water Level Monitoring in Three OPCJ Wells" (Edina Well No. 7, Edina OPCJ Test Well and Meadowbrook Golf Course Well). The work was conducted following the scope of work outlined in AECOM Proposal 04660-A60 submitted to Minnesota Pollution Control Agency (MPCA) in August 2009. The proposal was approved as stated in the Contract Work Order SFST1010 issued by the Minnesota Pollution Control Agency (MPCA) on August 10, 2009.

This report presents the results of continuous water level monitoring of the three wells conducted since July 2007 and completed at the beginning of February 2010. If you have any questions, please contact Peter Rzepecki at 763-852-4245 or Robert DeGroot at 763-852-4217.

Sincerely,

Piotr Rzepecki

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Contents

1.0 Introduction

Vinyl chloride (VC) contamination detected in the City of Edina Municipal Well Number 7 (ED-7) triggered a multi-phase investigation conducted since 2004. That investigation documented the presence of a large volatile organic compound (VOC) plume in the Prairie du Chien – Jordan Aquifer (OPCJ) and in the shallower aquifers, centered on an area within the boundaries of the City of St. Louis Park. Since the City of Edina uses the OPCJ groundwater for municipal water supply system, there is a concern that more of the St. Louis Park VOC plume may be drawn into the Edina area and its municipal wells.

One of the most important monitoring activities conducted since June 2007 with regard to VOC investigation in the area was simultaneous collection of continuous water level measurements from the three wells:

- Edina Well No. 7 (ED-7, MN Unique Well No. 00206474)
- Edina OPCJ Test Well (Edina Test Well, MN Unique Well No. 00748656)
- Meadowbrook Golf Course Well (Meadowbrook Well also known as W-119, further designated as Meadowbrook Well, MN Unique Well No. 00216009)

This group of wells straddles the boundary between the Cities of St. Louis Park and Edina (see Figure 1 – that figure also shows chlorinated VOC concentrations measured in groundwater samples collected from the Prairie du Chien–Jordan wells of the area). Monitoring this boundary area is important because groundwater contaminants migrate from St. Louis Park southward into Edina impacting its municipal wells.

The collected data revealed trends and dynamics of the groundwater system that are of particular importance to this investigation (see Section 2 of this report).

2.0 Water Level Data

2.1 History of Water Level Monitoring Activities

On March 8, 2005, Minnesota Department of Health (MDH) installed a transducer and data logger in ED-7 and conducted water level monitoring through June 7, 2005. However, water level in the well dropped below the transducer on June 7, 2005 and the monitoring was terminated. MDH reinstalled the transducer in ED-7 again on March 23, 2007 and continued collecting water level measurements once every 30 minutes until the present time.

AECOM has been operating a transducer and data logger in the Meadowbrook Well since May 19, 2005.

On June 6, 2007, AECOM staff installed a transducer and data logger in the newly constructed Edina Test Well and initiated measurements of water levels in that well once every 30 minutes. The Edina Test Well became the third OPCJ well in the area subject to continuous water level monitoring (the other two are ED-7 and Meadowbrook Well).

The transducer installed in Meadowbrook Well malfunctioned and stopped operating on June 6, 2009. The fixed transducer was reinstalled in Meadowbrook Well on September 18, 2009. Thus, groundwater flow direction could not be calculated for a period from June through September 2009.

2.2 Summary of the Monitoring Data

The entirety of the water level data collected beginning from 2005 is presented on Figure 2. Precipitation data (see Figure 3) and groundwater production data from significant nearby wells (see Table 1 and Figure 4) was also assembled for evaluation of the main factors influencing the direction of groundwater flow and groundwater level fluctuations.

2.2.1 Definition of Directional Classes Used for Presenting the Findings of this Report

Among the primary goals of the continuous water level monitoring at the three wells (ED-7, Edina Test Well and Meadowbrook Well) was calculating the direction of groundwater flow in the OPCJ aquifer near these three wells (see Figure 1). The calculated direction of groundwater flow is expressed as angle from 0° to 360°, where 0°, 90°, 180° and 360° represent East, North, West and South, respectively.

This report evaluates the influence of groundwater production patterns and other factors upon groundwater flow direction. Figures included in Appendix A demonstrate that the direction changes all the time.

The concept of “Directional Classes” was created and used to evaluate the relationship between groundwater flow direction and groundwater production from nearby wells. Production from nearby wells was considered the primary factor influencing changes in that direction. Fourteen municipal wells were identified to be present near the three monitoring wells with continuous water level monitoring data. All these municipal wells are within 1.4 mile radius of the Center Point. The Center

Point was defined as the middle of a triangle drawn using the locations of the three monitoring wells, ED-7, Edina Test Well and Meadowbrook Well (see Figure 1). Next, the direction of each of the fourteen municipal wells was determined relative to the Center Point and the well was assigned to one of the eight 45° Directional Classes. For instance, St. Louis Park municipal well No. 4 (SLP4) is located in a direction of 47° from the Center Point (on a scale of 0° to 360° measured counterclockwise, with 0° direction pointing exactly to the east – see Figure 1) and, therefore, was included in the 45° to 90° Directional Class.

These Directional Classes were used to evaluate/present not only the influence of groundwater production patterns upon groundwater flow direction, but also groundwater flow direction frequency, as shown on figures of Appendix A.

2.2.2 Precipitation Data

Figure 3 presents the average monthly precipitation in Hennepin County for the period of continuous water level monitoring. The data for that figure were taken from the website of the Minnesota Climatology Working Group (**http://climate.umn.edu/hidenannual/**).

2.2.3 Groundwater Production Data

Monthly groundwater production from Edina, St. Louis Park and Hopkins municipal wells within the 1.4 mile radius of the Center Point is presented in Table 1. Review of groundwater production data provided by the Minnesota Department of Natural Resources (MDNR – State Water Use Data System, SWUDS) revealed that municipal wells are the only significant pumping wells in the study area (see Reilly Tar Site/Meadowbrook Groundwater Model, St. Louis Park, Minnesota – Model Database Summary Report, the report prepared for MPCA by STS in June 30, 2004 is available at MPCA).

The wells included in Table 1 are grouped into seven Directional Classes. Note that there are no significant production wells in the direction 180° to 225° from the Center Point within 1.4 mile distance. Also, note that the three Hopkins wells (4, 5 and 6) were combined as one well – these wells are a considerable distance away and are located almost in the same direction from the Center Point.

Table 2 shows the combined monthly production data for all wells belonging to a particular Directional Class, while Table 3 combines monthly groundwater production within each Directional Class into three-month long seasons crudely corresponding to the four seasons of the year (calculations for the exact periods of the four seasons were not possible as the cities report groundwater production by calendar months). Table 3 also presents the calculated percentage of a production within each Directional Class as a portion of the total groundwater production (from all directions) for a particular season.

Figure 4 presents monthly groundwater production from each Directional Class for a period of continuous water level monitoring.

2.2.4 Water Level Data and Summary of Groundwater Flow Directions

Monitoring water levels at the three wells allowed calculation of a horizontal hydraulic gradient magnitude (ft/ft) and direction of groundwater flow in the important area of the boundary between the Cities of St. Louis Park and Edina. AECOM developed a proprietary Excel spreadsheet program to automate these gradient calculations. Figure 5 summarizes the results of these calculations (note that there is a data gap for a period of June through September of 2009). More detailed information is provided in Appendix A.

2.2.5 Summary Description of Groundwater Flow Direction and Hydraulic Gradients by Season

Figures 2A through 22A of Appendix A provide more detailed information that is organized and discussed below by season – from Summer 2007 through Winter 2009.

Summer of 2007

Figure 2A demonstrates that during the summer of 2007 groundwater was flowing from the direction of St. Louis Park toward Edina 27.06% of the time (1.75% + 7.48% + 17.83%) (flow angle range from 225° to 360°; explanation: groundwater flow direction 0° or 360 ° equals flow toward East, flow direction 180° equals flow toward West, etc.).

Figure 3A demonstrates that groundwater flow during summer of 2007 was frequently shifting from one direction to another.

Figure 4A demonstrates that most of the time groundwater gradient during the Summer of 2007 was in a range of 0.0001 ft/ft to 0.0005 ft/ft (explanation: water level along the direction of groundwater flow was dropping from 1 foot to 5 feet per 10,000 feet of horizontal distance along the direction of groundwater flow).

Fall of 2007

Figure 5A demonstrates that during the Fall of 2007 groundwater was flowing from the direction of St. Louis Park toward Edina (flow angle range from 225° to 360°) 48.41% of the time (1.87% + 8.20% + 38.34%). That 48.41% does not include a two week period of time when the data is missing.

Based on inspection of Figure 6A, it is interpreted that during that time of missing data, groundwater was flowing mainly toward the northeast part of Edina, in the direction bracketed by 315° to 360°. Figure 6A demonstrates that groundwater flow during the Fall of 2007 was flowing most of the time in the direction ranging from 315° to 360° (toward northeast part of Edina). In the late part of Fall 2007 however, groundwater was flowing in the direction ranging from 45° to 90° (toward north-northeast and away from Edina).

Figure 7A demonstrates that in the early part of the Fall 2007 groundwater gradient was in a range of 0.0002 ft/ft to 0.0004 ft/ft, while during the mid- and late part of the Fall 2007, groundwater gradient was higher - in a range of 0.0005 ft/ft to 0.0008 ft/ft.

Winter of 2008

Figure 8A demonstrates that during the Winter of 2008, groundwater was flowing from the direction of St. Louis Park toward Edina (flow angle range from 225° to 360°) only 0.98% of the time (0.00% + 0.00% + 0.98%).

Figure 9A demonstrates that groundwater flow during the Winter of 2008 was not changing direction most of the time, migrating predominantly in the E – ENE direction (the direction ranging from 0° to 45°), away from Edina.

Comparison of Figures 10A and 7A demonstrates that groundwater gradient was higher most of the time during the Winter of 2008 compared to the Summer and Fall of 2007 - in a range of 0.0004 ft/ft to 0.0012 ft/ft.

Spring of 2008

Figure 11A demonstrates that during the Spring of 2008 groundwater was flowing from the direction of St. Louis Park toward Edina (flow angle range from 225° to 360°) 42.78% of the time (0.00% + 0.13% + 42.65%).

Figure 12A demonstrates that groundwater flow during the Spring of 2008 was not significantly changing direction most of the time, migrating predominantly toward the east (the direction ranging from 315° to 45°), toward Minneapolis and northeast Edina.

Figure 13A demonstrates that most of the time groundwater gradient during the Spring of 2008 was in a range of 0.0004 ft/ft to 0.0008 ft/ft.

Summer of 2008

Figure 14A demonstrates that during the Summer of 2008 groundwater was flowing predominantly toward northeast Edina – 69% of the time (flow angle range from 315° to 360°).

Figure 15A demonstrates that groundwater flow during the Summer of 2008 was migrating predominantly in east-southeast direction (the direction ranging from 315° to 360°).

Figure 16A demonstrates that most of the time groundwater gradient during summer of 2008 was in a range of 0.0002 ft/ft to 0.0008 ft/ft.

Fall of 2008

Figure 17A demonstrates that during the Fall of 2008 groundwater was migrating from the direction of St. Louis Park toward Edina (flow angle range from 225° to 360°) 43.83% of the time (0.30% + 0.90% + 42.63%).

Figure 18A demonstrates that groundwater flow during the Fall of 2008 was migrating predominantly in an eastern direction, although during late Fall the direction shifted more toward the northeast, with periods of time when groundwater was moving to the west.

Figure 19A demonstrates that groundwater gradient during the Fall of 2008 was changing over a wide range of values (from close to 0.0000 ft/ft to over 0.0012 ft/ft) with general decline in gradients toward the end of Fall.

Winter of 2009

Figure 20A demonstrates that during the Winter of 2009 groundwater was migrating predominantly from the direction of St. Louis Park toward northeast Edina (flow angle range from 315° to 360°) - 75.23% of the time.

Figure 21A demonstrates that groundwater flow during the Winter of 2009 was migrating predominantly in an eastern direction with periodical reversions to the northwestern direction (135°).

Figure 22A demonstrates that groundwater gradient during the Winter of 2009 was in a range of 0.0000 ft/ft to 0.002 ft/ft with gradients generally increasing toward the end of winter.

Spring of 2009

Figure 23A demonstrates that during the Spring of 2009 groundwater was flowing from the direction of St. Louis Park toward Edina (flow angle range from 225° to 360°) 25.97% of the time (0.05% + 0.11% + 25.81%).

Figure 24A demonstrates that groundwater flow during the Spring of 2009 was predominantly toward the northeast (the direction ranging from 0° to 45° - toward Minneapolis), while periodically groundwater was migrating toward the southeast (the direction ranging from 315° to 360° - toward northeast Edina).

Figure 25A demonstrates that during the Spring of 2009 groundwater gradients were fluctuating over a wide range of values, from 0.0000 ft/ft (no groundwater movement in horizontal direction) to 0.002 ft/ft.

Fall of 2009

Figure 26A demonstrates that during the Fall of 2009 groundwater was migrating from the direction of St. Louis Park toward Edina (flow angle range from 225° to 360°) 15.42% of the time (1.37% + 0.41% + 13.64%).

Figure 27A demonstrates that groundwater flow during the Fall of 2009 was migrating predominantly in a western direction (toward Hopkins), although during late Fall the direction shifted more toward the east (toward Minneapolis and northeast Edina).

Figure 28A demonstrates that groundwater gradient during the Fall of 2009 was decreasing from about 0.0035 ft/ft early in the Fall to near zero later in the Fall.

2.2.6 New Survey of the Three Monitoring Wells

The three monitoring wells (ED-7, Edina Test Well and Meadowbrook Well) were surveyed to verify the values of the elevation of measuring points. These elevations were used to calculate the water level elevations which, in turn, were used to calculate gradients. The survey was conducted on September 16, 2009 using the local benchmarks and their elevations provided by the Cities of Edina and St. Louis Park. Below is the summary of the survey results:

Well Surveyed: ED-7
Benchmark Used: The hydrant on Sherwood Rd west side of street across from the driveway to well house
Benchmark Elevation: 958.69 ft
Elevation of Measuring Point – old measurement: 954.10 ft
Elevation of Measuring Point – new measurement: 954.27 ft
Difference (new minus old measurement): 0.17 ft

Well Surveyed: Edina Test Well
Benchmark Used: The hydrant at the corner of Glengarry Pkwy and Vernon Ave
Benchmark Elevation: 920.46 ft
Elevation of Measuring Point – old measurement: 902.03 ft
Elevation of Measuring Point – new measurement: 901.97 ft
Difference (new minus old measurement): -0.06 ft

Well Surveyed: Meadowbrook Well
Benchmark Used: The hydrant at NW corner of Colorado Ave S and Meadowbrook Blvd
Benchmark Elevation: 895.58 ft
Elevation of Measuring Point – old measurement: 895.85 ft
Elevation of Measuring Point – new measurement: 895.84 ft
Difference (new minus old measurement): -0.01 ft

For the sake of consistency, all the elevation and gradient calculations presented in this report were carried out using the old measuring point elevations for the monitoring wells. Limited budget available for this project prevented AECOM from repeating all the calculations using the new survey data. However, the calculations for the data collected during the Fall of 2009 were carried out using both the old and the new survey data. Comparison of Figures 26A, 27A and 28A (presenting the results of calculations based on the old survey data) and Figures 26A', 27A' and 28A' (presenting the results of calculations based on the new survey data) shows no significant differences between the results of both calculations. Apparently the differences between the old and the new survey measurements are relatively small and they do not result in significantly different results of the gradient calculations.

2.2.7 SCADA Water Elevation Data and Comparison with Monitoring Well Data

Recently the Cities of St. Louis Park and Edina installed the SCADA (supervisory control and data acquisition) systems to control and monitor operations of their municipal wells. AECOM requested the depth to water data for several of these wells to visually inspect how groundwater production influences water levels and flow direction in the area of the three monitoring wells. The data for the following wells was acquired:

- SLP 4 – data covering the period from July 16, 2009 to February 10, 2010 with 30 minute frequency
- ED2, ED3, ED4, ED6, ED13, ED16, ED17 and ED20 – data covering the period from December 29, 2009 to January 30, 2010 with 15 minute frequency (although several lapses are present in data for some of these wells)

Thus, a more or less complete set of continuous water level data for the nearby municipal wells is available for the month of January 2010. The processed water level and gradient direction data for January 2010 are presented on a series of figures included in Appendix B.

Figure 1B shows the January 2010 hydrographs of the Edina and St. Louis Park municipal wells. Figures 2B, 3B and 4B summarize the information on groundwater flow direction and gradients for that time period. During January 2010 groundwater was migrating predominantly in the east-southeastern direction, from St. Louis Park area toward Edina (83.87% of the time).

Figure 5B consists of three stacked-up charts showing groundwater flow direction changing with time (the upper chart – Figure 5B a), hydrographs for the municipal wells east and west of the monitoring wells' area (the middle chart – Figure 5B b), and hydrographs for the municipal wells southeast and southwest of the monitoring wells' area (the bottom chart – Figure 5B c). Inspection of this figure reveals that the only significant period of groundwater flow shifting away from the predominant east-southeast direction (toward Edina - flow angle range from 315° to 360°) occurred on January 7, 2010. That January 7th shift (groundwater flow toward Minneapolis - flow angle range from 0° to 45°) coincides with a significantly long period of continuous pumping from ED13 (located west of the monitoring wells' area) and a significantly long period of non-pumping from ED4 (located southeast of the monitoring wells' area). However, since the pumping/non-pumping periods for ED13 and ED4 extend beyond January 7, the shift of groundwater flow direction on that day and the subsequent reversal to the flow to the predominant flow direction were apparently caused by other factors as well, not represented by the data of Figure 5B. It is likely that other wells located further away exert a combined influence on groundwater levels and flow direction in the area.

Figures 6B, 7B and 8B show hydrographs of each of the three monitoring wells superimposed on hydrographs of the nearby municipal wells. Inspection of these graphs reveals more local influences of the pumping cycles upon water levels in the monitoring wells, compared to influences shown on Figure 5B.

Figure 6B shows that water level in Meadowbrook Well is influenced by pumping from ED13 and SLP4 more than by pumping from ED2.

Figure 7B shows that water level in Edina OPCJ Test Well is influenced by pumping from ED20 more than by pumping from ED13 or ED4 – ED20 is the closest production well to Edina OPCJ Test Well.

Figure 8B shows that water level in ED7 is clearly influenced by pumping from all the nearby municipal wells.

Figure 8B shows changes in water level in all three monitoring wells in January 2010. Water levels in these wells are all correlated with one another but amplitude of fluctuations vary from well to well and from period to period, most likely due to changing frequencies of pumping from the nearby municipal wells.

3.0 DISCUSSION

3.1 Seasonal Water Level Fluctuations

Figure 2 presents the entire water level data collected from the three OPCJ wells in the period from March 2005 to February 2010. It demonstrates the presence of a highly dynamic groundwater system with the distinct seasonal cycles of water levels. The amplitude of water level changes between summer and winter regularly exceeds 40 feet and this pattern of seasonal fluctuations is consistent.

Comparison of Figure 2 (hydrographs) and Figure 3 (monthly precipitation in Hennepin County) reveals that the depth of water level decline during summer time is not clearly correlated with the level of precipitation during that time. Sometimes a smaller decline in water levels during summer corresponds to higher levels of precipitation and, vice versa, larger decline in water levels corresponds to lower levels of precipitation, like in the case of comparison between the summers of 2005 and 2006. However, sometimes the reverse relationship is observed, like in the case of comparison between the summers of 2006 and 2007 (when higher levels of precipitation in summer of 2007 correspond to higher declines in water levels, compared to summer 2006). This apparent lack of a direct relationship between groundwater flow direction and precipitation patterns is likely the result of the fact that the monitored groundwater is in a deep aquifer separated from a shallow aquifer (subject to recharge by precipitation) by several aquitards and hydrostratigraphic units.

Clearly the amplitude of water level changes is a function of groundwater production levels that are shifting not only from season to season (different level of water demand caused by weather patterns) but also from area to area (municipalities' decisions influenced by other factors).

Figure 4 illustrates that groundwater demand is changing with season with groundwater production generally much higher during summers 2007, 2008 and 2009, compared to winters 2008 and 2009.

3.2 Groundwater Production and Flow Direction

The data collected during continuous water level monitoring allowed calculation of hydraulic gradients and horizontal direction of groundwater migration on an hourly basis. The results of these calculations are presented on Figure 5 and on figures of Appendix A (Figures 1 – 28). These figures illustrate that direction of groundwater flow and horizontal hydraulic gradient continuously vary in response, primarily to the changing configuration of water production from the area's municipal wells.

Figures 2, 5, 8, 11, 14, 17, 20, 23 and 26 of Appendix A present the following average parameters calculated for each Directional Class during each of the nine seasons covered by this analysis:

- percentage of the time during a given season that groundwater flowed in a particular 45° range of directions (form the Center Point - Directional Class)
- average horizontal hydraulic gradient for groundwater flowing in a particular 45° range of directions (form the Center Point - Directional Class)
- percentage of groundwater production from wells located in a particular 45° range of directions (form the Center Point - Directional Class)

What is of particular importance for the Edina VOC study is the fact that groundwater is migrating from St. Louis Park toward the northeast part of Edina a large portion of the time. During the monitoring period, groundwater was moving from St. Louis Park toward Edina (in the range of directions from 225° to 360° or 0°) about:

- 27% of the time during Summer of 2007
- 48% of the time during Fall of 2007
- 1% of the time during Winter of 2008
- 43% of the time during Spring of 2008
- 69% of the time during Summer of 2008
- 44% of the time during Fall of 2008
- 75.23% of the time during Winter of 2009
- 26% of the time during Spring of 2009
- 15% of the time during Fall of 2009; and also
- 96% of the time during January of 2010

As this tabulation above and Figure 8A illustrate, the only season, among the nine seasons monitored, when groundwater was consistently migrating away from Edina was Winter of 2008.

The regional data indicate that the general groundwater flow direction in the southeastern part of Hennepin County is toward the east–southeast (Hennepin County Geological Atlas, Plate 6). Thus, the regional flow direction affects, to a degree, the flow of contaminated groundwater from St. Louis Park toward northeast Edina. However, changing groundwater directions and gradients at Edina and St. Louis Park are also significantly influenced by an intense production from the area's municipal wells.

Inspection of Figures 2, 5, 8, 11, 14, 17, 20, 23 and 26 of Appendix A and Table 3 reveals the following:

- Groundwater flow toward Edina appears to be somewhat correlated with increased production from the Edina wells. However, other influences discussed in the following bullets complicate this would-be simple relationship.
- The only season with groundwater flowing consistently away from Edina (away from flow direction range 270° to 360°), Winter 2008, coincides with high groundwater production coming from 0° to 90° range of directions (production from ED2 and SLP4). High production from these wells apparently diverts groundwater flow from the southeastern direction to a more eastern direction.
- Exceptionally high rate of groundwater flow toward Edina (flow in the direction range 270° to 360°) observed during Winter 2009 (75% of the time) appears to coincide with low levels of production from ED13 (located west of the Center Point – see Figure 1) combined with high levels of production from ED2 (located east of the Center Point). Similar factors may be responsible for a very high rate of groundwater flow toward Edina observed during January 2010 (96% of the time).
- The data accumulated during this water level monitoring program indicate that there is no simple relationship between groundwater flow toward Edina and season of a year. This is

illustrated by a vastly different flow direction measured during winter of 2008 and winter of 2009 or during Summer 2007 vs. Summer 2008.

It is important to note that the relationships described in the above three points are not strong. The monitored groundwater system is highly dynamic and analyzing monthly or seasonal averages is likely to result in missing the more direct and evident relationships. Hourly data presented on Figures 3, 6, 9, 12, 15, 18, 21, 24 and 27 of Appendix A document a presence of a highly dynamic system with gradients sharply shifting within hours.

Figure 5 of Appendix B compares the calculated groundwater flow direction during January of 2010 with water levels measured in the nearby municipal wells. This comparison reveals that pumping from the nearby wells influences groundwater flow direction but the relationship is not strong. It is likely that other wells located further away exert a combined influence on groundwater levels and flow direction in the area. Figures 6, 7 and 8 of Appendix B illustrate the influence exerted upon water levels in monitoring wells by pumping from nearby wells.

Figures 4, 7, 10, 13, 16, 19, 22, 25 and 28 of Appendix A illustrate the frequency and magnitude of changes in horizontal gradients. Comparison of groundwater production configurations between the summer 2007 (low gradients – Figure 4A) and Winter 2008 (high gradients – Figure 22A) reveals that the gradients flatten (decrease) when production from ED2 is low and production from ED13 is high (see also Table 1) and vice versa. This is to be expected as low production from ED2 (east of the Center Point) and high production from ED13 (west of the Center Point) counters the regional gradient which is toward the east. The practical conclusion is that maintaining high levels of production from ED13 slows down groundwater movement toward Edina.

Figure 1A shows that groundwater flows from the area covered by the three monitoring wells toward ED13 (135 to 180 deg directional class) 9.74% of the time during the 838 day monitoring period (June 2007 through January 2010 with some data gaps within that period of time – but the total time of monitoring with complete set of water level data from all three wells is 838 days).

When groundwater flows toward ED13 (and Hopkins wells 4, 5 and 6 which are located in that same direction but a bit further west – see Figure 1) the average gradient is high (0.00153 ft/ft). However review of A series of Figures 2, 5, 8, 11, 14, 17, 20, 23 and 26 shows that occurrences of flow in that direction does not happen that often – mainly during Fall 2008, and Winter, Spring and Fall 2009 – Fall 2009 in particular! That Fall of 2009 data completely dominates the calculated statistics. During the Fall of 2009 gradient of flow in the direction of ED13 was also well above average.

If groundwater can flow to ED13 from east-southeast (where the three monitoring wells are), it is also very likely flowing from the northeast where the center of the VOC and PAH plumes are. This is something to keep in mind because, as of 2009, VOC concentrations in ED13 show an upward trend (although not as much as in ED2) and PAH concentrations in ED13 are also increasing, although the PAH concentrations still remain well below the drinking water standard (personal communication from Bill Gregg, AECOM). So, it is reasonable to predict that at some time in the future ED13 may also need to be connected to a granular activated carbon treatment plant. That is because shutting down ED13 would be unacceptable. If ED13 were to stop pumping, the VOC plume (and perhaps the PAH plume as well) would almost certainly migrate or be pulled more toward the south and contaminate the other, more southern Edina city wells, which so far remain unaffected by VOCs.

3.3 Basic Assumption Used in Data Processing and Interpretation

The presented results are based on the assumption that the calculated horizontal hydraulic gradient in the OPCJ aquifer is uniform throughout the area covered by the three monitoring wells that were part of the continuous water level monitoring program. Since Meadowbrook Well is located a considerable distance from the other two wells (ED-7 and ED Test Well), the calculated gradients and gradient directions may considerably deviate from the actual gradients and gradient directions. This is because gradients are likely to change with location, particularly in a complex and dynamic groundwater system in the investigated area.

4.0 Recommendations

Figure 1A illustrates that groundwater migrates from St. Louis Park toward Edina a large portion of the time. Considering the fact that the important Edina groundwater producing well, ED2, is located in the 0° to 45° directional range (see Figure 1), groundwater flows toward Edina 77% of the time (directional range from 225° to 45°). However this is a somewhat conservative estimate as much of the groundwater flow in the 0° to 45° directional range is converging on the important St. Louis Park well – SLP4. If we exclude ED2 from that calculation, groundwater flows toward Edina 44% of the time (directional range from 225° to 360°).

Such a high frequency and rate of contaminated groundwater flow toward Edina implicates that continuous water level monitoring in the St. Louis Park – Edina boundary area is important. It allows a better protection of Edina's groundwater resources. For instance, knowledge about groundwater flow direction prevailing at a given period of time could be used to regulate operations of the new Edina water treatment plant that is currently under design. During periods of time when groundwater moves away from Edina, production from the OPCJ wells connected to the plant could be decreased and/or shifted to the wells located further south, without running a risk of pulling the VOC plume further south. Such knowledge would be helpful for scheduling of the needed periodical plant maintenance shut-downs.

Two of the three OPCJ water level monitoring wells, Meadowbrook Well and ED7, will soon not be available for monitoring of background water levels. Thus, continuation of water level monitoring in the future would necessitate construction of two new replacement wells. AECOM considered recommendation of using some private wells for monitoring via agreement with the wells' owners. However, the OPCJ private wells in the area are completed in the very top portion of the Prairie du Chien formation, above the contaminated portion of the aquifer. Water levels in that top portion of the aquifer may differ somewhat from water levels in the lower, more transmissive sections of the formation. This renders these wells questionable as candidates for water level monitoring wells.

If new monitoring wells were to be constructed, careful consideration should be given to their locations. The well to replace the Meadowbrook Well should be located further south and closer to Edina (as the Meadowbrook Well is located a considerable distance from the other two monitoring wells). The well to replace the ED7 well should be located some distance away from ED7 and any other production well. Ideally, the three monitoring wells should be located at the vertices of an equilateral triangle covering the boundary area between St. Louis Park and Edina. They should be located no further away from each other than about 2,000 feet. Such monitoring network would represent an improvement over the current water level monitoring network which was used to generate the data presented in this report.

The data generated by this project will be used to update the Reilly Tar Site / Meadowbrook Groundwater Model. The updated model will be used to run a series of predictive simulations to support the design of the new Edina water treatment plant and configuration of groundwater production from the Edina municipal wells.

5.0 General Qualifications

AECOM professional services have been performed, data collected, analyzed and findings obtained in accordance with generally accepted engineering and hydrogeologic principles and standard practices. No other warranty, either expressed or implied, is made. AECOM assumes no responsibility for data or interpretations made by others. AECOM accepts no responsibility for application or interpretation of the results by anyone other than the client.

Tables

Table 1. Water Production from Wells 1.4 Miles Around the Center of the "Continuous Water Level Monitoring Triangle"

AECOM Project No. 60137283 / 60145589

Directional Class	0 to 45 deg	45 to 90 deg		90 to 135 deg	135 to 180 deg			225 to 270 deg	270 to 315 deg	315 to 360 deg		
Well	ED2	SLP4	SLP6	SLP10	HOPKINS 4, 5 and 6	ED13	ED15	ED16	ED6	ED3	ED4	ED17
Well Production (millions of gallons)												
Jul-07	28	40	0	45	119	46	35	39	33	2	21	6
Aug-07	28	41	0	36	100	33	14	24	17	1	12	5
Sep-07	29	40	0	28	85	35	5	23	15	1	3	0
Oct-07	31	39	0	0	68	43	0	2	16	0	0	0
Nov-07	26	37	0	2	62	38	0	0	21	0	1	0
Dec-07	33	40	0	18	62	43	0	0	33	0	1	0
Jan-08	34	39	0	20	68	11	0	0	29	0	0	0
Feb-08	29	38	0	25	59	14	0	0	17	0	8	0
Mar-08	32	40	0	24	56	45	0	0	19	0	15	0
Apr-08	23	38	0	26	54	7	0	0	5	0	0	0
May-08	28	39	0	34	66	41	0	7	14	0	14	0
Jun-08	30	40	0	32	77	25	2	20	34	2	12	2
Jul-08	28	44	0	38	101	42	10	30	34	0	31	13
Aug-08	31	42	0	42	100	43	7	28	41	0	42	6
Sep-08	28	40	0	38	85	34	1	9	37	0	33	0
Oct-08	29	37	0	27	62	39	0	0	38	0	30	0
Nov-08	26	43	0	23	57	43	0	0	29	0	11	0
Dec-08	27	44	0	24	57	38	0	0	28	0	12	0
Jan-09	19	42	0	25	54	38	0	0	28	0	12	0
Feb-09	14	40	0	26	52	37	0	0	26	0	16	0
Mar-09	22	25	0	32	57	0	0	0	38	0	20	0
Apr-09	4	30	0	14	56	4	1	1	30	24	10	2
May-09	20	45	0	18	83	43	5	6	39	22	38	28
Jun-09	11	43	0	10	84	40	1	7	20	25	39	11
Jul-09	26	47	0	34	98	28	3	16	23	32	40	10
Aug-09	21	49	0	38	83	34	0	14	14	22	42	3
Sep-09	36	46	0	8	83	42	2	13	7	34	37	2
Oct-09	29	48	0	0	56	23	0	0	1	11	12	0
Nov-09	25	47	0	0	53	14	0	0	0	4	22	0
Dec-09	32	49	0	0	54	19	0	0	0	0	27	0
Total:	776	1230	0	685	2152	944	86	240	688	180	561	87

Table 2. Water Production from Groups of Wells (by Direction) 1.4 Miles Around the Center of the "Continuous Water Level Monitoring Triangle"

AECOM Project No. 60137283 / 60145589

Directional Class	0 to 45 deg	45 to 90 deg	90 to 135 deg	135 to 180 deg	225 to 270 deg	270 to 315 deg	315 to 360 deg
Wells:	ED2	SLP4, SLP6	SLP10	HOPKINS 4, 5 and 6, ED13, ED15	ED16	ED6	ED3, ED4, ED17
Well Group Production (millions of gallons)							
Jul-07	28	40	45	200	39	33	29
Aug-07	28	41	36	148	24	17	17
Sep-07	29	40	28	125	23	15	4
Oct-07	31	39	0	111	2	16	0
Nov-07	26	37	2	100	0	21	1
Dec-07	33	40	18	105	0	33	1
Jan-08	34	39	20	79	0	29	0
Feb-08	29	38	25	73	0	17	8
Mar-08	32	40	24	101	0	19	15
Apr-08	23	38	26	61	0	5	0
May-08	28	39	34	107	7	14	14
Jun-08	30	40	32	104	20	34	16
Jul-08	28	44	38	154	30	34	44
Aug-08	31	42	42	151	28	41	48
Sep-08	28	40	38	120	9	37	33
Oct-08	29	37	27	101	0	38	30
Nov-08	26	43	23	100	0	29	11
Dec-08	27	44	24	95	0	28	12
Jan-09	19	42	25	92	0	28	12
Feb-09	14	40	26	89	0	26	16
Mar-09	22	25	32	57	0	38	20
Apr-09	4	30	14	61	1	30	35
May-09	20	45	18	131	6	39	87
Jun-09	11	43	10	125	7	20	75
Jul-09	26	47	34	130	16	23	82
Aug-09	21	49	38	117	14	14	68
Sep-09	36	46	8	127	13	7	73
Oct-09	29	48	0	79	0	1	23
Nov-09	25	47	0	66	0	0	26
Dec-09	32	49	0	73	0	0	27
Total:	776	1230	686	3183	240	688	828

Table 3. Water Production from Groups of Wells (by Direction and by Season) 1.4 Miles Around the Center of the "Continuous Water Level Monitoring Triangle"

AECOM Project No. 60137283 / 60145589

Directional Class		0 to 45 deg	45 to 90 deg	90 to 135 deg	135 to 180 deg	225 to 270 deg	270 to 315 deg	315 to 360 deg
Wells:		ED2	SLP4, SLP6	SLP10	HOPKINS 4, 5 and 6, ED13, ED15	ED16	ED6	ED3, ED4, ED17
Well Group Production (millions of gallons)								
Jul-07		28	40	45	200	39	33	29
Aug-07	Summer 2007	28	41	36	148	24	17	17
Sep-07		29	40	28	125	23	15	4
% of Total Production:		8.60%	12.23%	11.03%	47.69%	8.72%	6.62%	5.11%
Oct-07		31	39	0	111	2	16	0
Nov-07	Fall 2007	26	37	2	100	0	21	1
Dec-07		33	40	18	105	0	33	1
% of Total Production:		14.53%	18.75%	3.19%	51.45%	0.30%	11.36%	0.42%
Jan-08		34	39	20	79	0	29	0
Feb-08	Winter 2008	29	38	25	73	0	17	8
Mar-08		32	40	24	101	0	19	15
% of Total Production:		15.26%	18.79%	11.08%	40.75%	0.00%	10.51%	3.61%
Apr-08		23	38	26	61	0	5	0
May-08	Spring 2008	28	39	34	107	7	14	14
Jun-08		30	40	32	104	20	34	16
% of Total Production:		11.99%	17.46%	13.68%	40.49%	3.97%	7.96%	4.45%
Jul-08		28	44	38	154	30	34	44
Aug-08	Summer 2008	31	42	42	151	28	41	48
Sep-08		28	40	38	120	9	37	33
% of Total Production:		8.12%	11.91%	11.04%	40.16%	6.40%	10.60%	11.77%
Oct-08		29	37	27	101	0	38	30
Nov-08	Fall 2008	26	43	23	100	0	29	11
Dec-08		27	44	24	95	0	28	12
% of Total Production:		11.30%	17.07%	10.26%	40.85%	0.00%	13.12%	7.40%
Jan-09		19	42	25	92	0	28	12
Feb-09	Winter 2009	14	40	26	89	0	26	16
Mar-09		22	25	32	57	0	38	20
% of Total Production:		8.80%	17.16%	13.30%	38.27%	0.00%	14.87%	7.61%
Apr-09		4	30	14	61	1	30	35
May-09		20	45	18	131	6	39	87
Jun-09		11	43	10	125	7	20	75
% of Total Production:		4.29%	14.50%	5.11%	39.00%	1.75%	11.04%	24.32%
Sep-09		36	46	8	127	13	7	73
Oct-09		29	48	0	79	0	1	23
Nov-09		25	47	0	66	0	0	26
Dec-09		32	49	0	73	0	0	27
% of Total Production:		14.56%	22.72%	0.98%	41.40%	1.53%	0.93%	17.89%
Total:		608	946	606	2593	197	644	529

Figures

Figure 2. Edina Well No. 7, Edina Well No. 13, Meadowbrook Golf Course Well (W119) and Edina OPCJ Test Well Hydrographs

AECOM Project No. 60137283 / 60145589

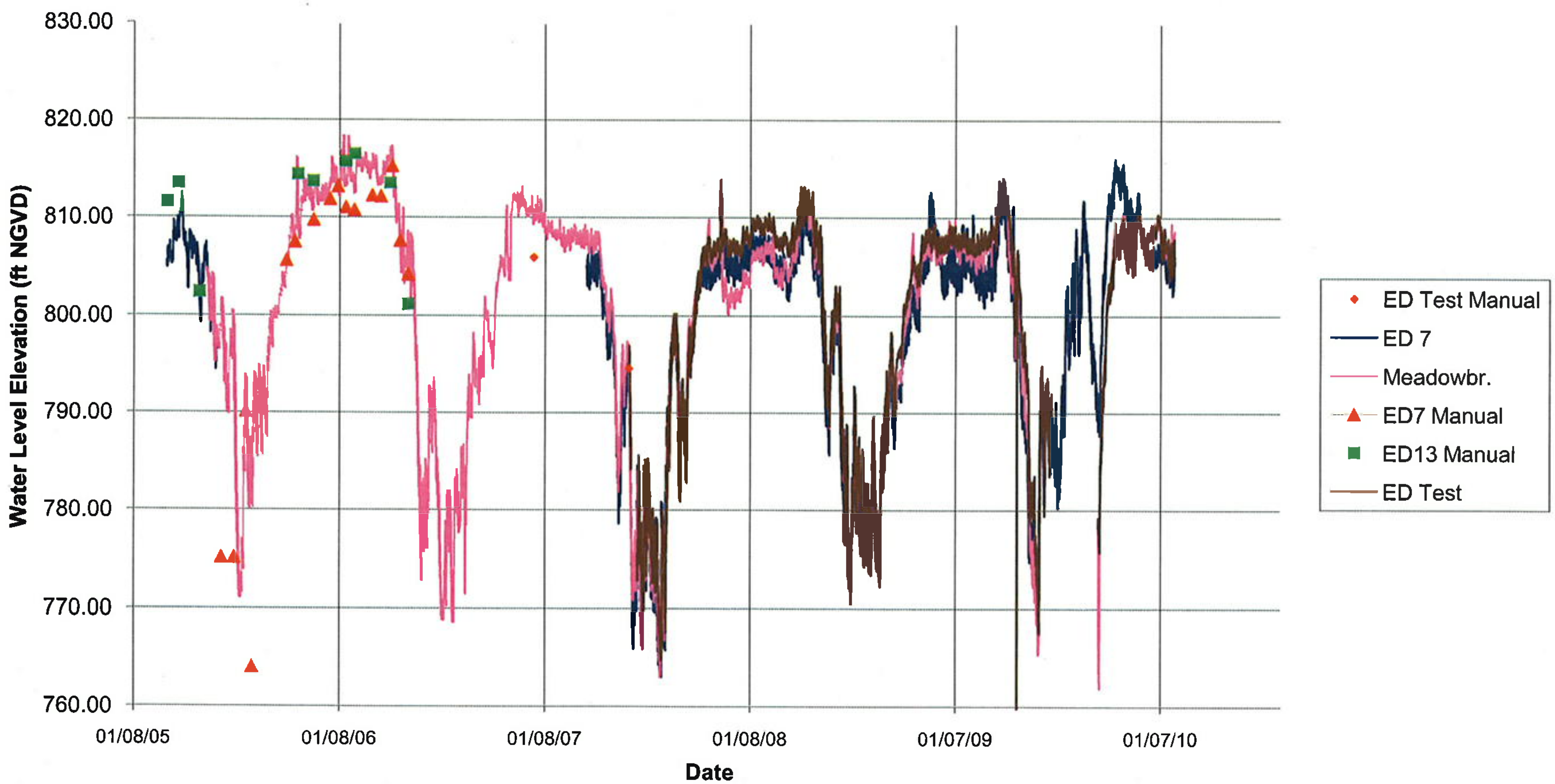


Figure 3. Monthly Precipitation in Hennepin County
AECOM Project No. 60137283 / 60145589

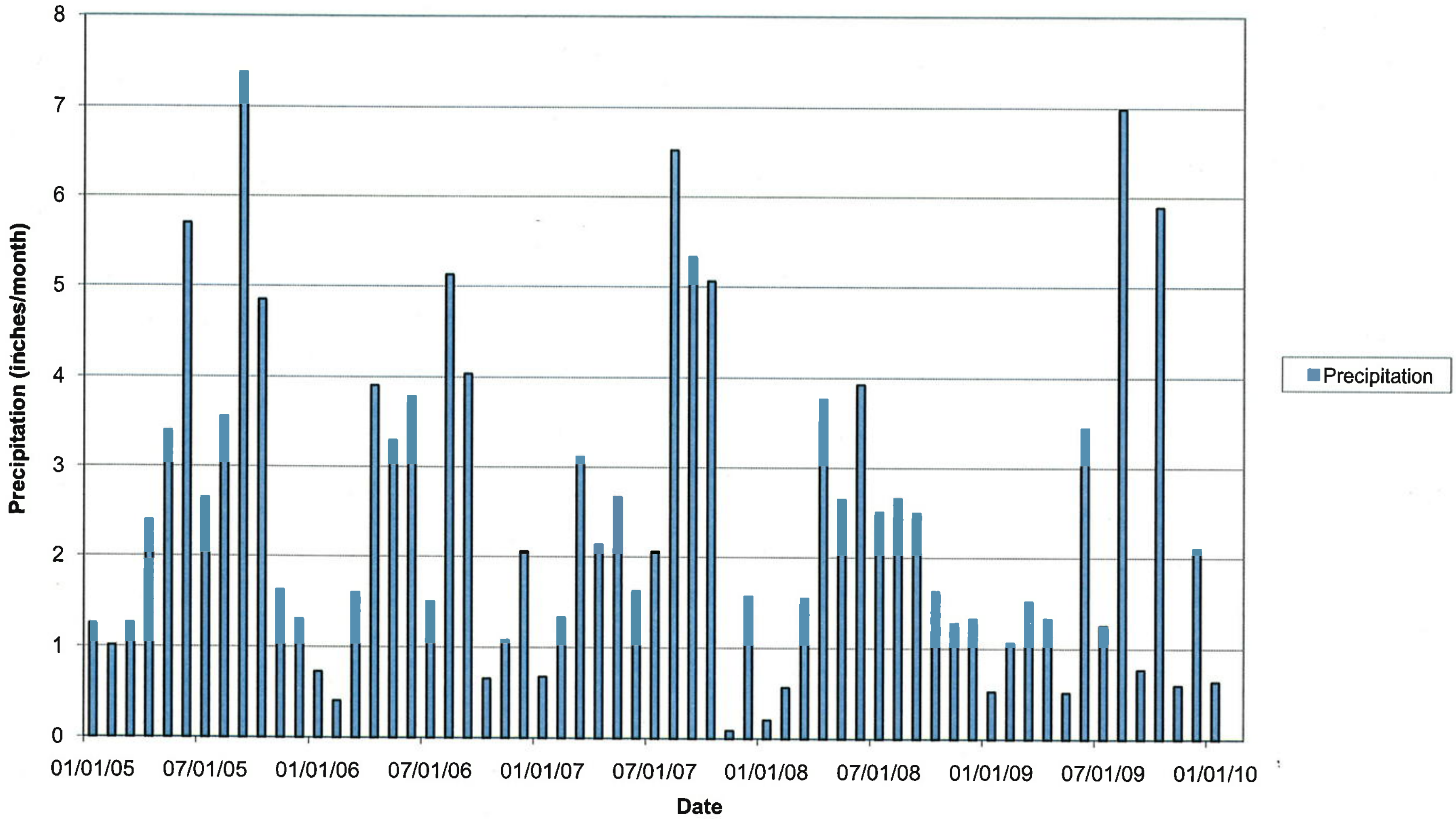


Figure 4. Monthly Water Production from "Directional Well Groups"
AECOM Project No. 60137283 / 60145589

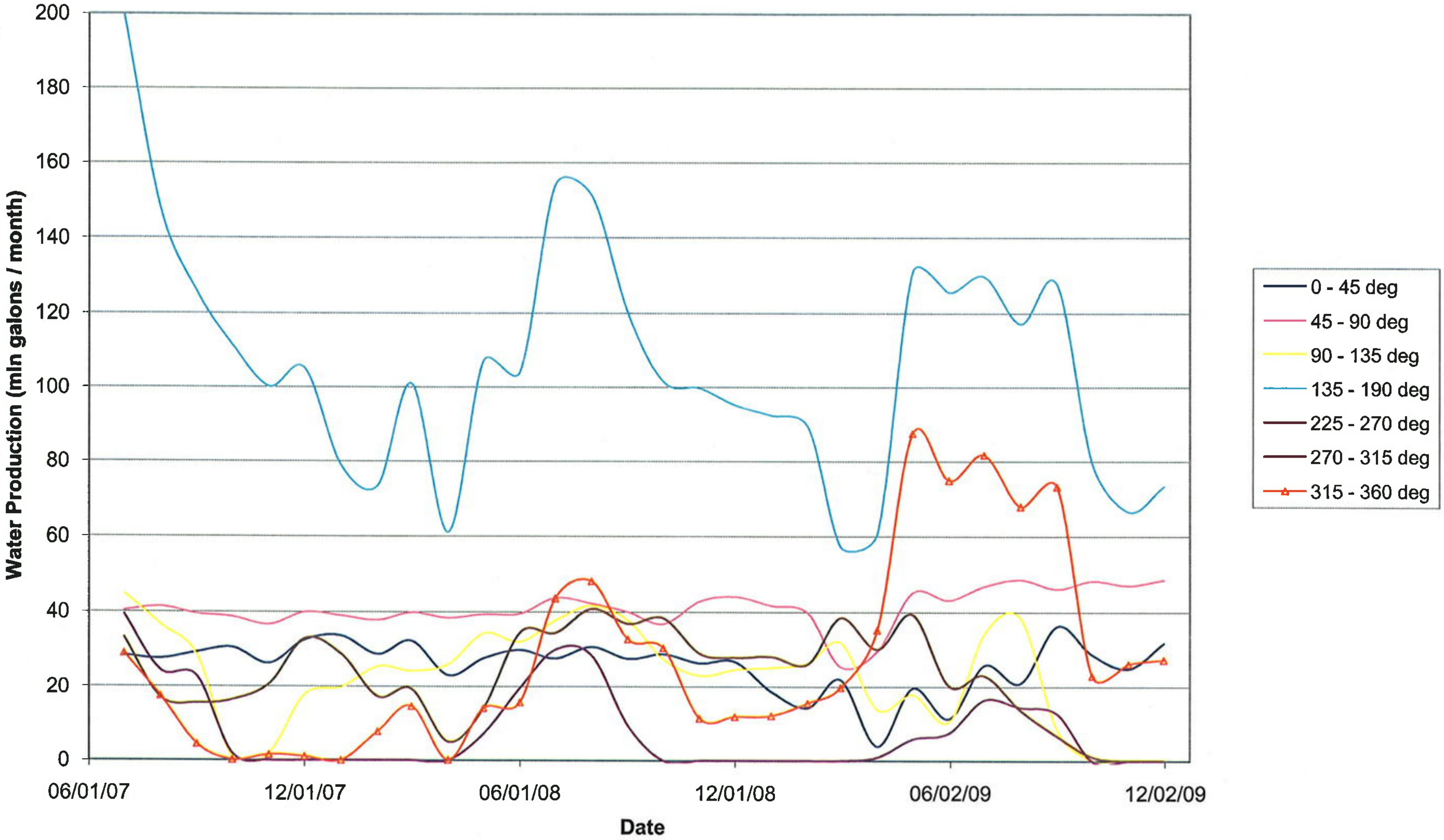
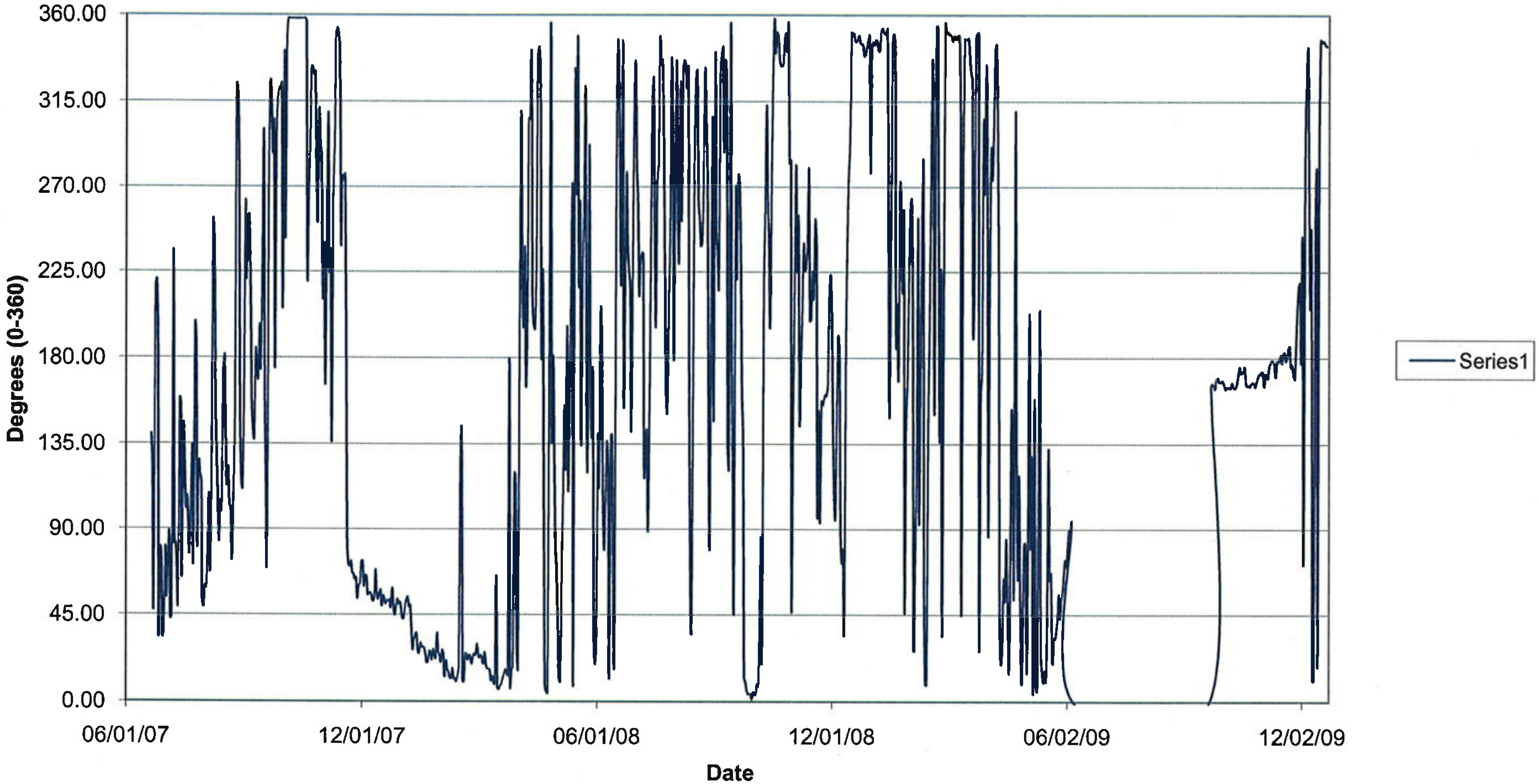


Figure 5. Changing OPCJ Gradient Direction - St. Louis Park - Edina
June 21, 2007 - March 20, 2009

AECOM Project No. 60137283 / 60145589



Appendices

Appendix A – Changes in Groundwater Flow Direction and Gradients by Season

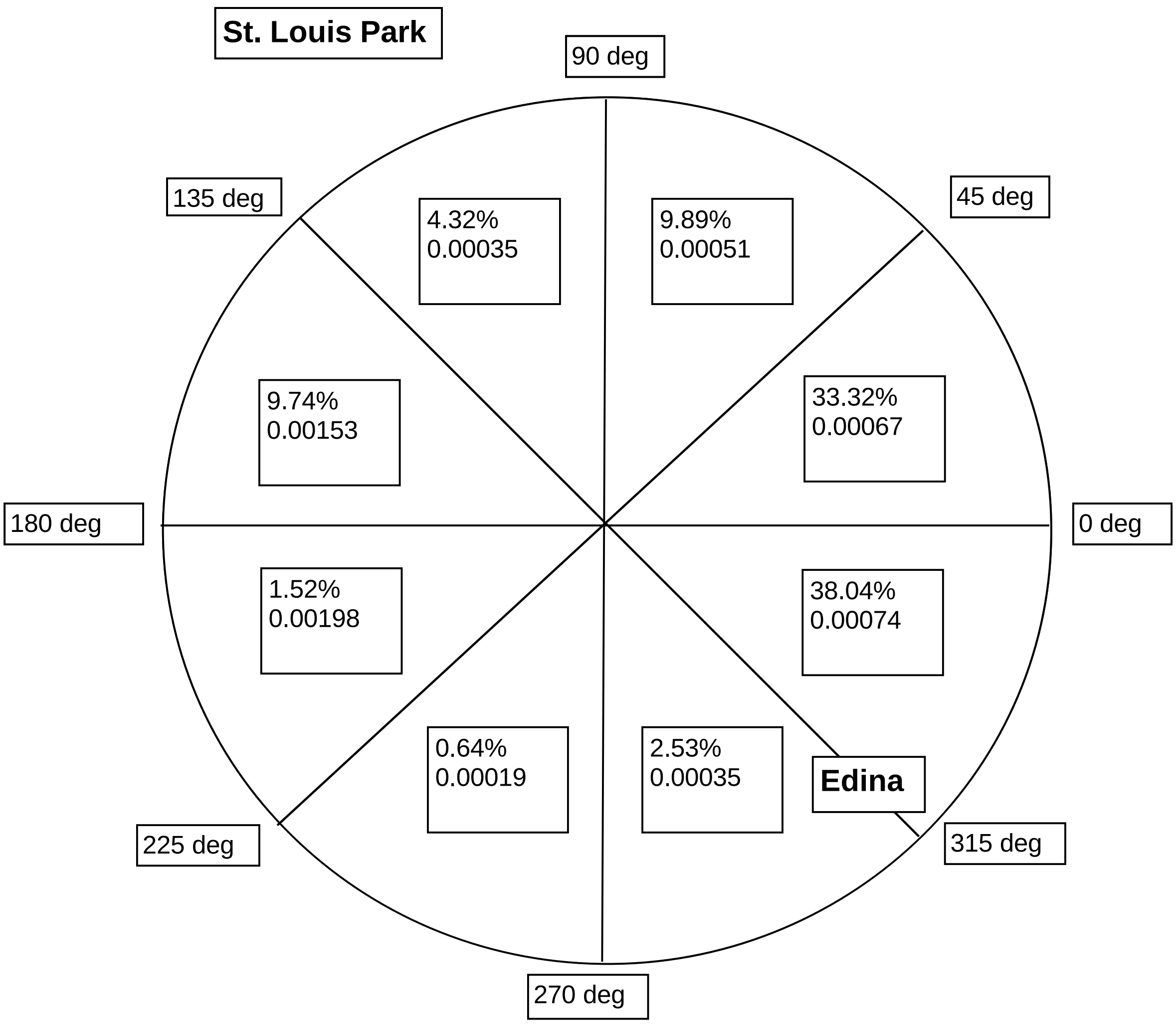
Appendix B – Comparison of Water Levels Measured in Municipal Wells and Monitoring Wells in January 2010

Appendix A

Changes in Groundwater Flow Direction and Gradients by Season

Figure 1A. OPCJ Gradient Direction (0 - 360 deg)
Average for a Monitored Period from June 2007 through January 2010
(838 days monitored)

AECOM Project 60137283 / 60145589

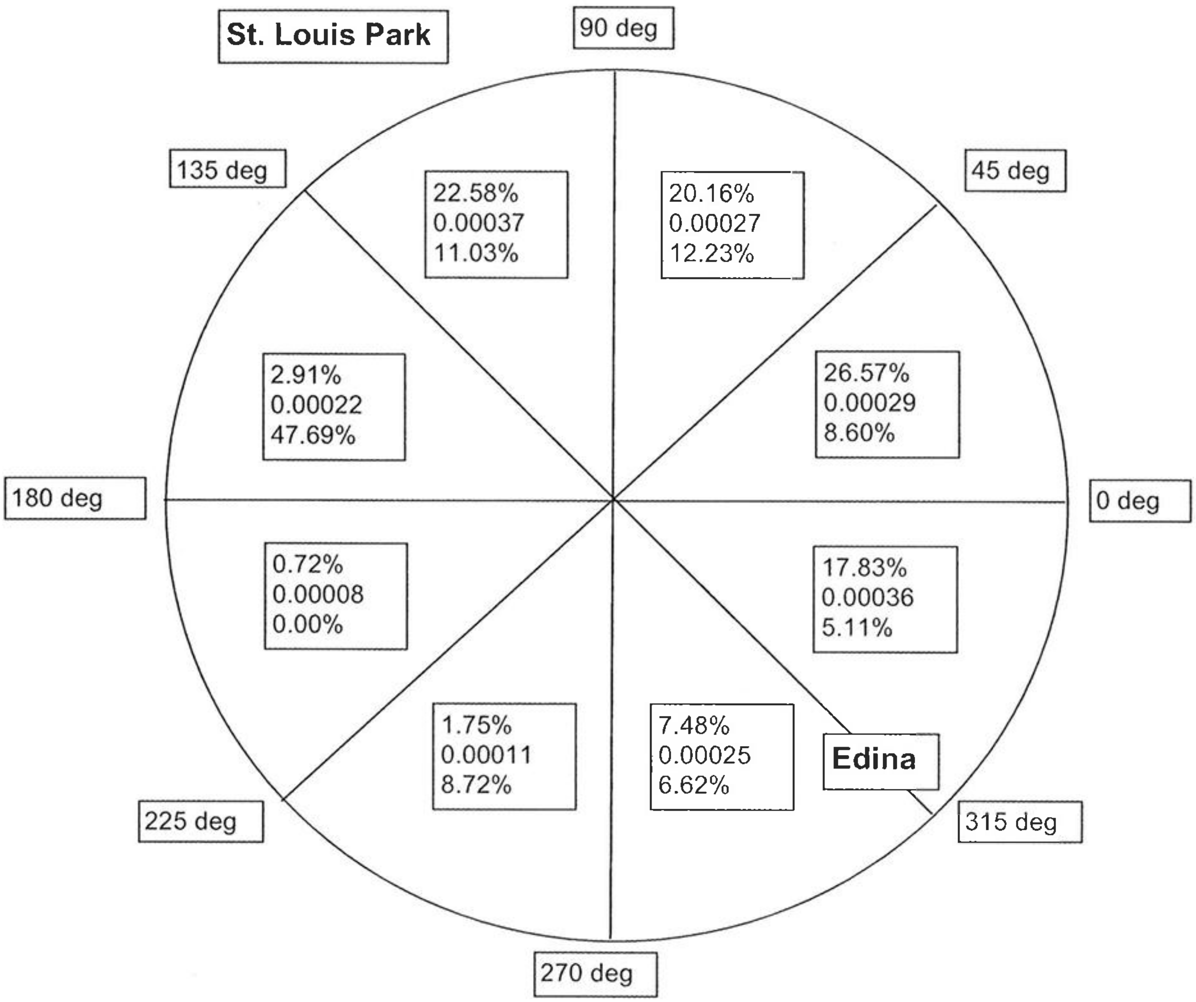


Note: The figure shows:

39.01%	- percentage of the time during the 838 days of monitoring that groundwater flowed in a particular 45 deg direction range
0.00067	- average gradient when groundwater flowed in that particular 45 deg directional range
90 deg	- North
180 deg	- West
270 deg	- South
0 deg	- East

Figure 2A. OPCJ Gradient Direction (0 - 360 deg) and Magnitude (ft/ft)
Summer 2007 (6/21/07 - 9/21/07)

AECOM Project 60137283 / 60145589



Note: The figure shows:

17.83%	- percentage of the time during Summer 2007 groundwater flowed in a particular 45 deg direction range
0.00036	- average gradient when groundwater flowed in that particular 45 deg direction range
5.11%	- percentage of groundwater production from wells in that particular 45 deg direction range
90 deg	- North
180 deg	- West
270 deg	- South
0 deg	- East

Figure 3A. Changing OPCJ Gradient Direction - St. Louis Park / Edina - Summer 2007
AECOM Project No. 60137283 / 60145589

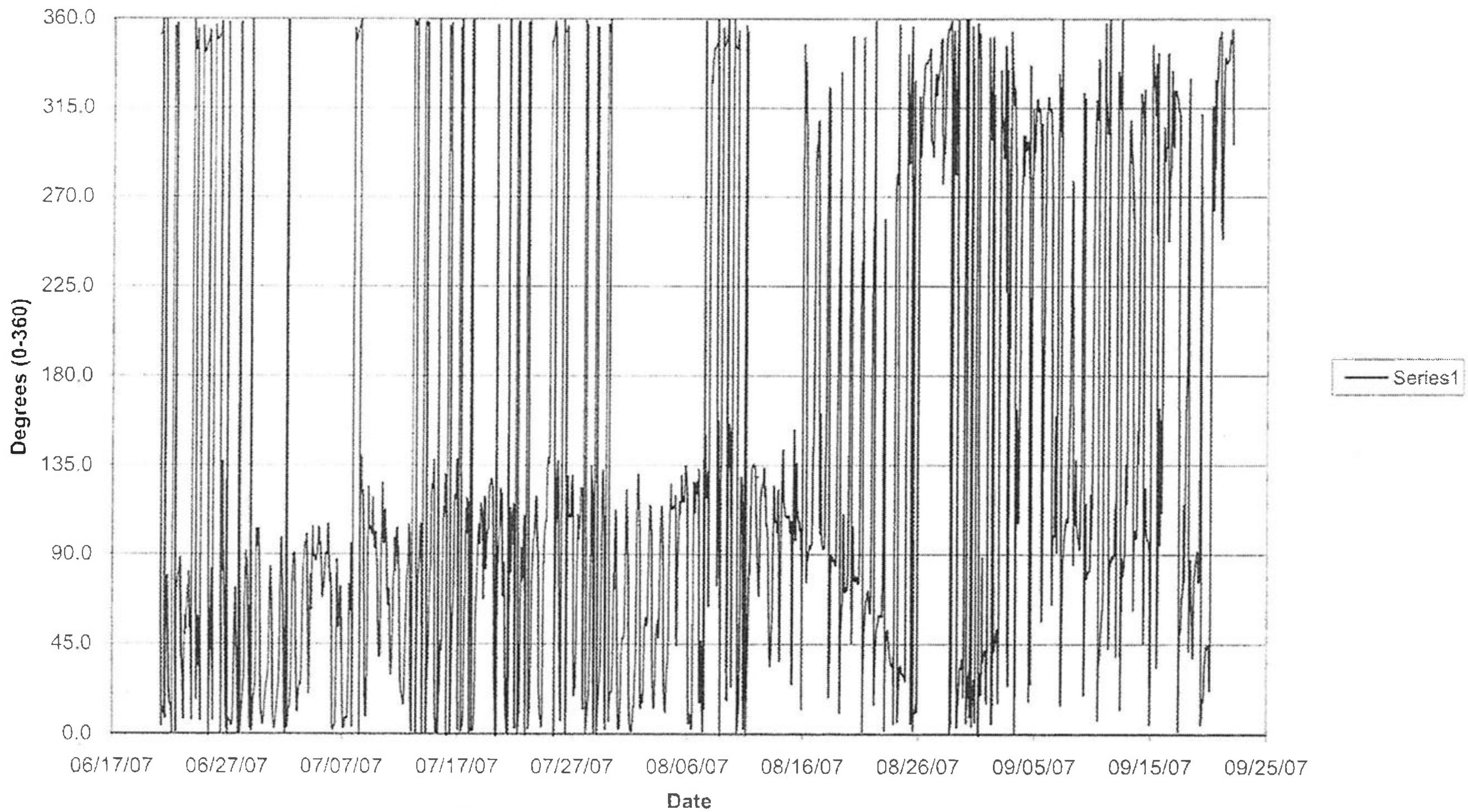


Figure 4A. Change in OPCJ Gradient Magnitude with Time - St. Louis Park / Edina - Summer 2007
AECOM Project No. 60137283 / 60145589

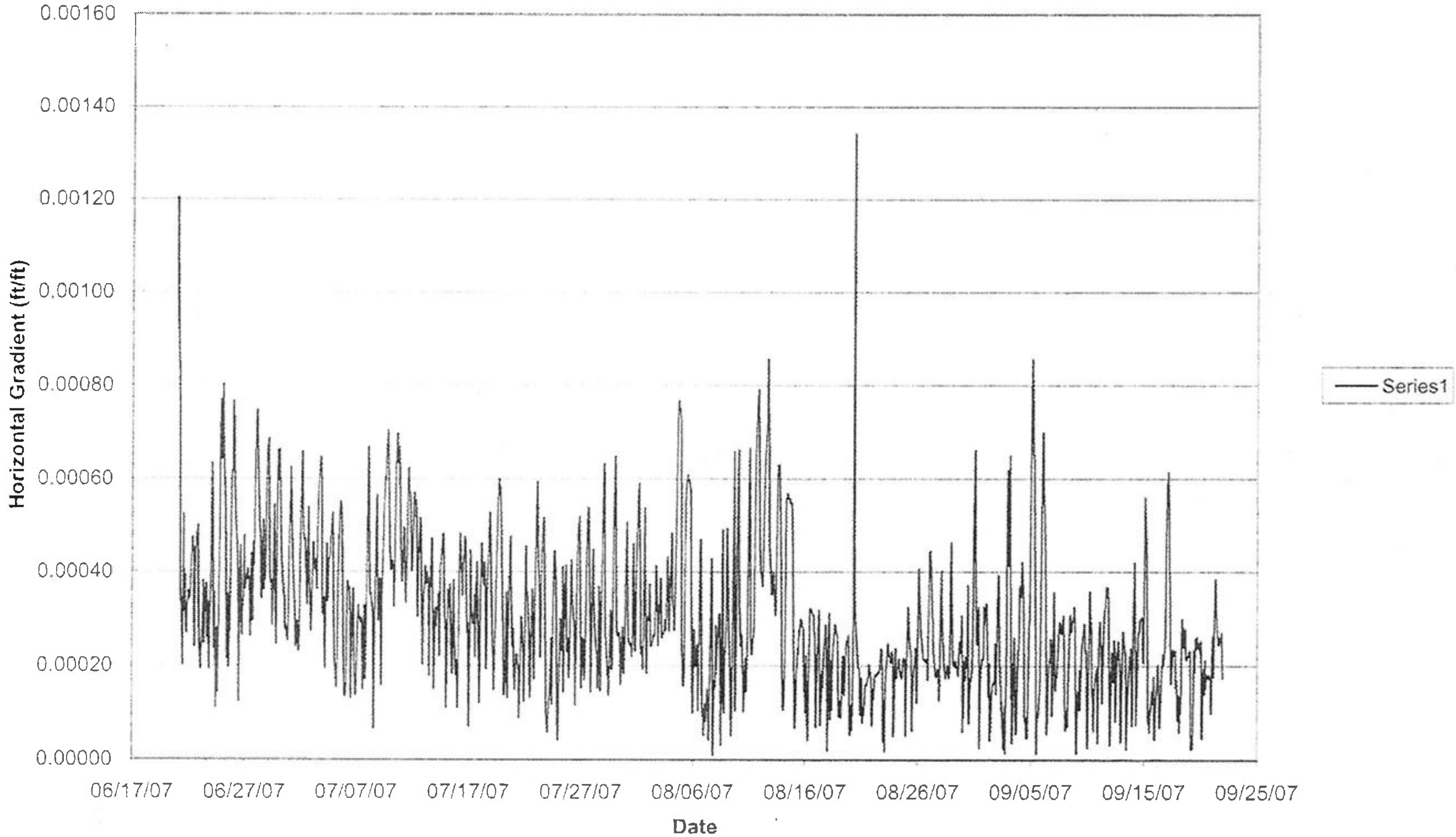
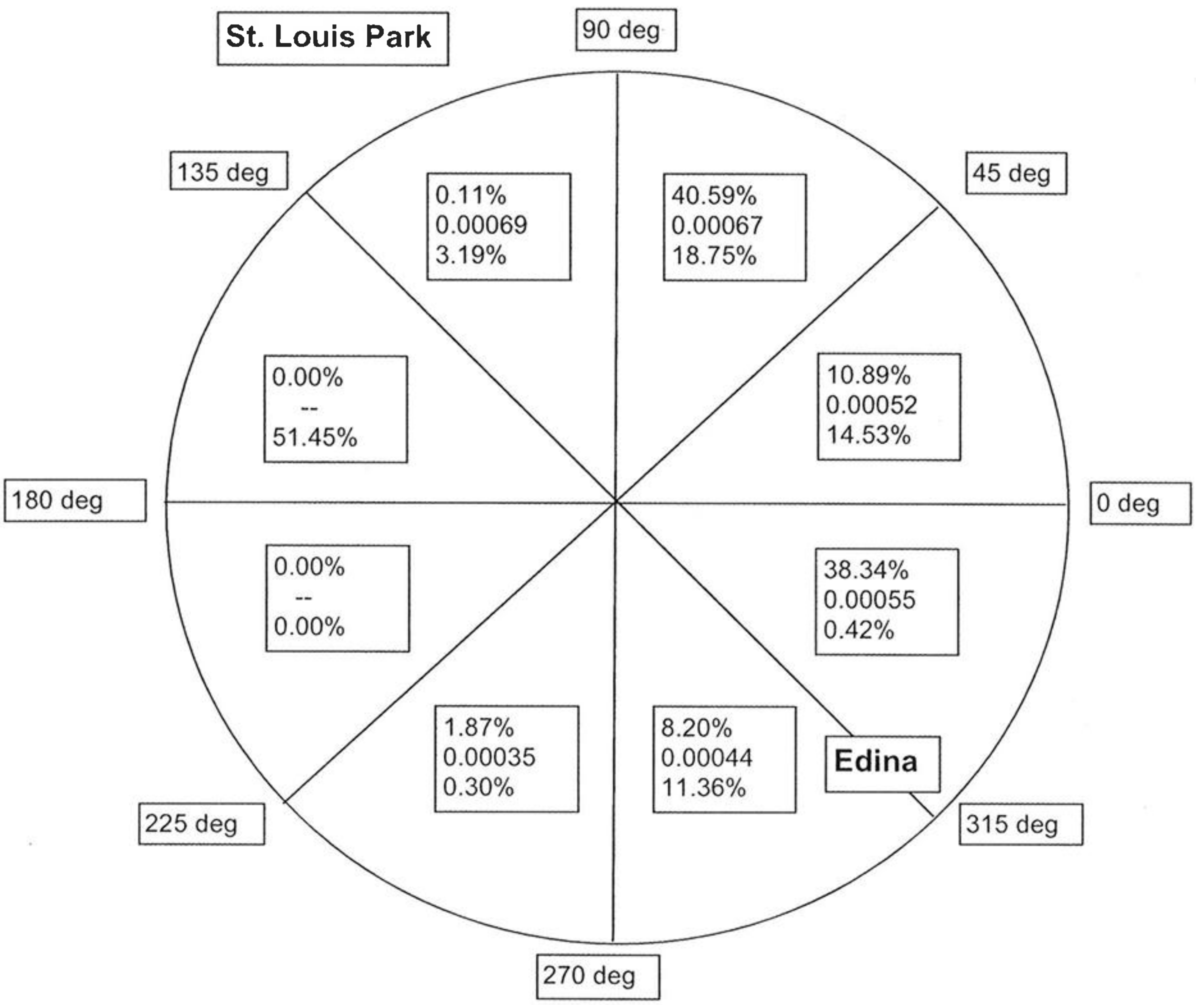


Figure 5A. OPCJ Gradient Direction (0 - 360 deg) and Magnitude (ft/ft) Fall 2007 (9/22/07 - 12/21/07)

AECOM Project 60137283 / 60145589



Note: The figure shows:

38.34%	- percentage of the time during Fall 2007 groundwater flowed in a particular 45 deg direction range
0.00055	- average gradient when groundwater flowed in that particular 45 deg direction range
0.42%	- percentage of groundwater production from wells in that particular 45 deg direction range
90 deg	- North
180 deg	- West
270 deg	- South
0 deg	- East

Figure 6A. Changing OPCJ Gradient Direction - St. Louis Park / Edina - Fall 2007
AECOM Project No. 60137283 / 60145589

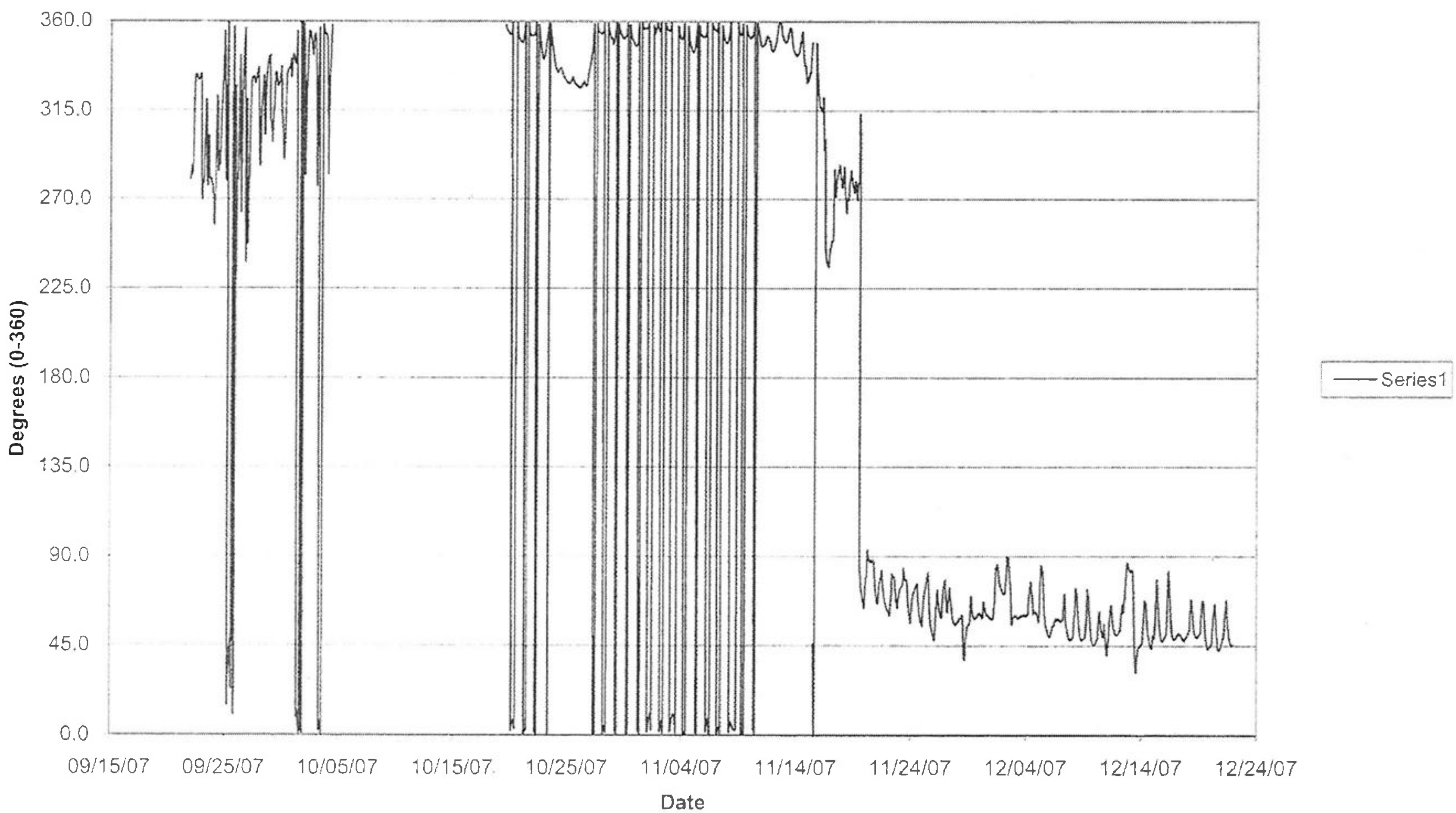


Figure 7A. Change in OPCJ Gradient Magnitude with Time - St. Louis Park / Edina - Fall 2007
AECOM Project No. 60137283 / 60145589

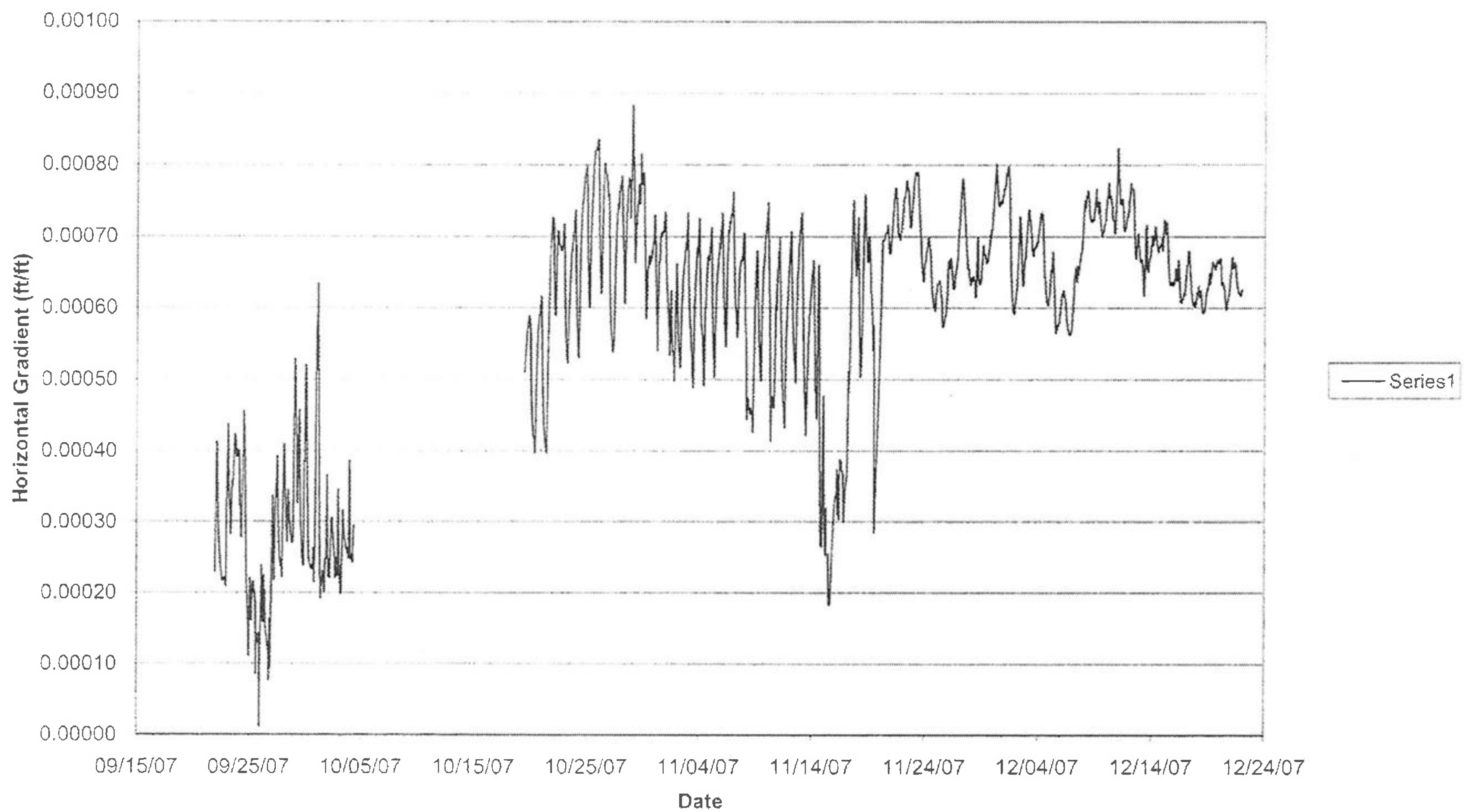
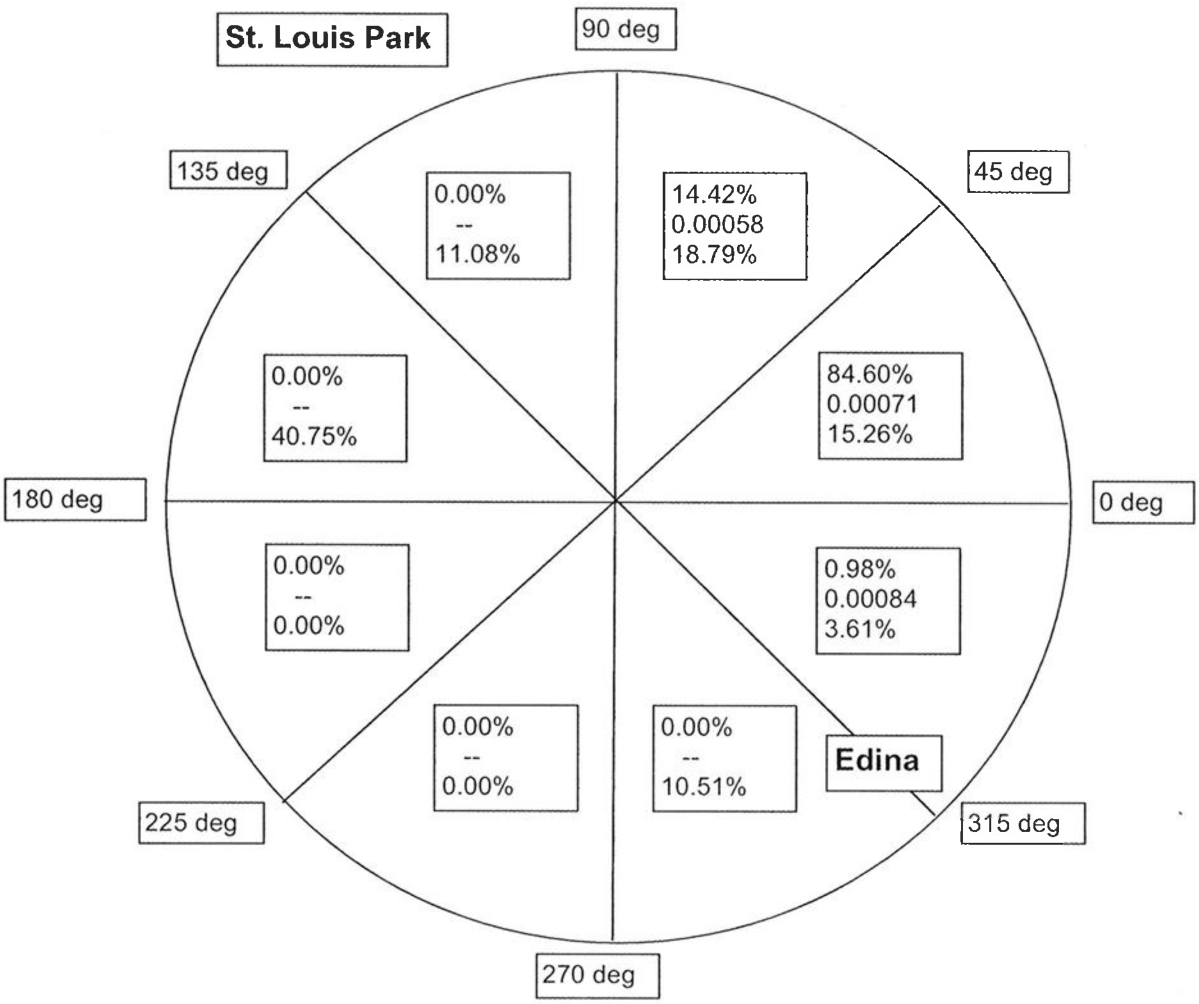


**Figure 8A. OPCJ Gradient Direction (0 - 360 deg) and Magnitude (ft/ft)
Winter 2008 (12/22/07 - 3/19/08)**

AECOM Project 60137283 / 60145589



Note: The figure shows:

0.98%	- percentage of the time during Winter 2008 groundwater flowed in a particular 45 deg direction
0.00084	- average gradient when groundwater flowed in that particular 45 deg direction range
3.61%	- percentage of groundwater production from wells in that particular 45 deg direction range
90 deg	- North
180 deg	- West
270 deg	- South
0 deg	- East

Figure 9A. Changing OPCJ Gradient Direction - St. Louis Park / Edina - Winter 2008
AECOM Project No. 60137283 / 60145589

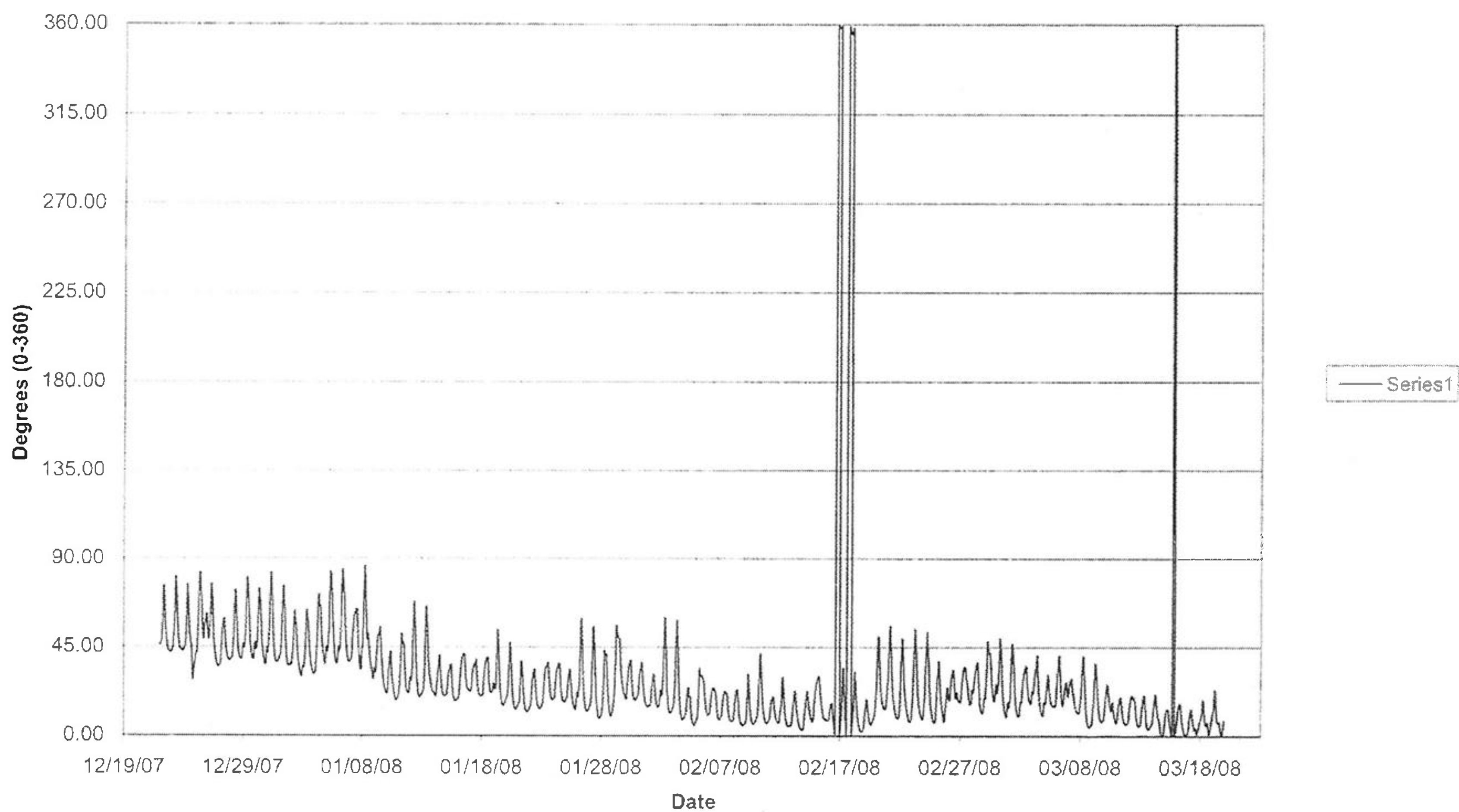


Figure 10A. Change in OPCJ Gradient Magnitude with Time - St. Louis Park / Edina - Winter 2008

AECOM Project No. 60137283 / 60145589

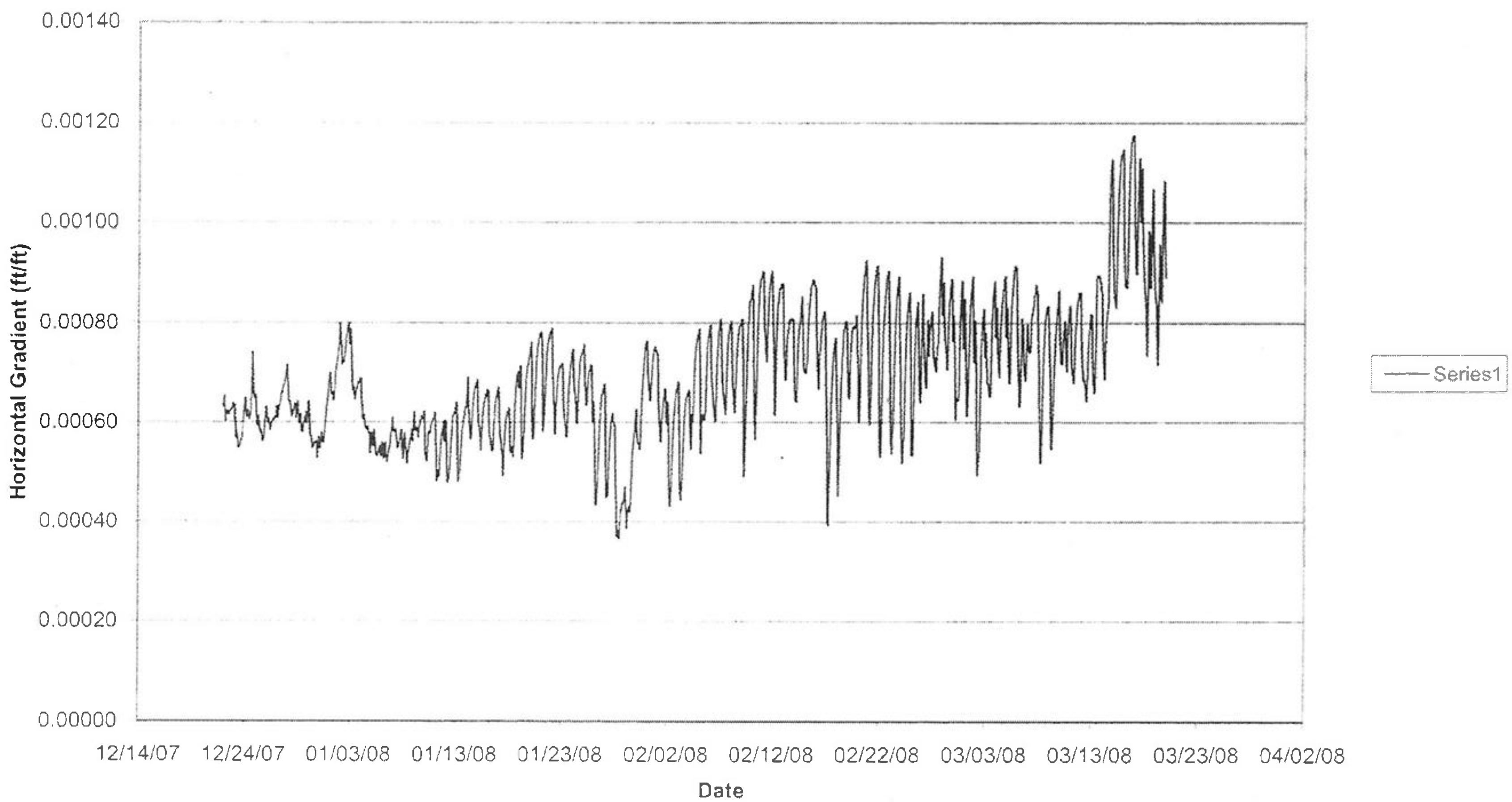
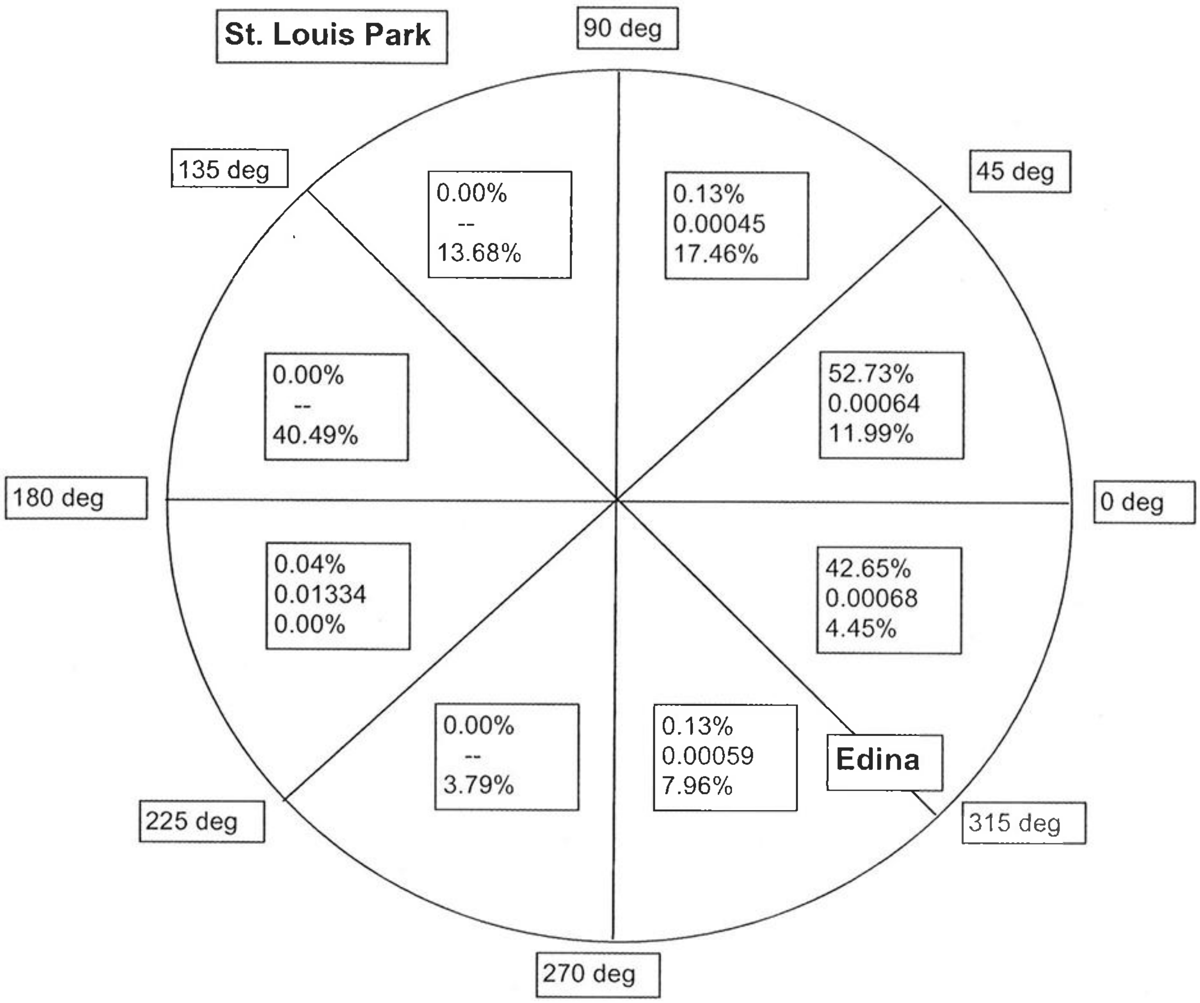


Figure 11A. OPCJ Gradient Direction (0 - 360 deg) and Magnitude (ft/ft) Spring 2008 (3/20/08 - 6/20/08)

AECOM Project 60137283 / 60145589



Note: The figure shows:

42.65%	- percentage of the time during Spring 2008 groundwater flowed in a particular 45 deg direction
0.00068	- average gradient when groundwater flowed in that particular 45 deg direction range
4.45%	- percentage of groundwater production from wells in that particular 45 deg direction range

90 deg - North
180 deg - West
270 deg - South
0 deg - East

Figure 12A. Changing OPCJ Gradient Direction - St. Louis Park / Edina - Spring 2008
AECOM Project No. 60137283 / 60145589

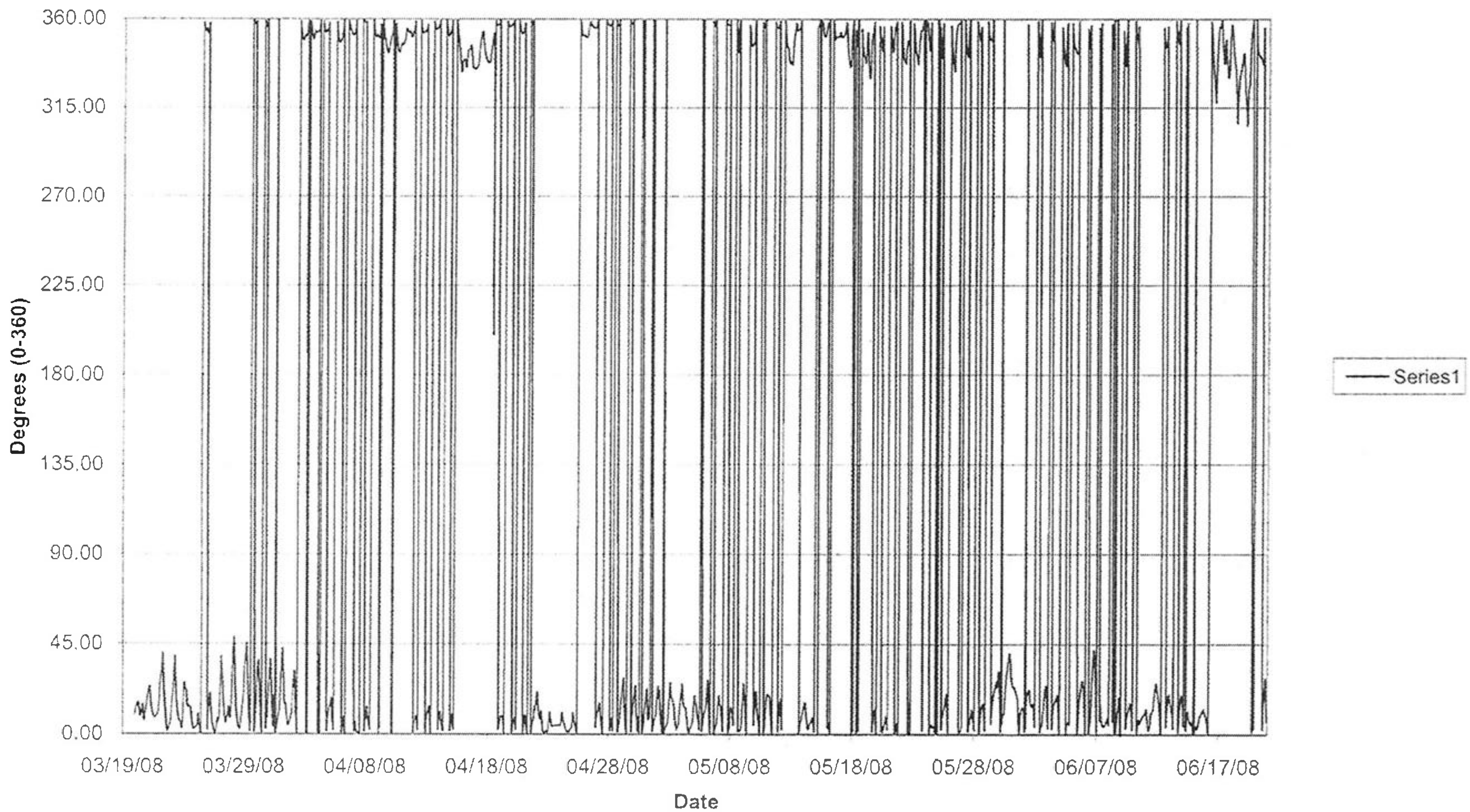


Figure 13A. Change in OPCJ Gradient Magnitude with Time - St. Louis Park / Edina - Spring 2008
AECOM Project No. 60137283 / 60145589

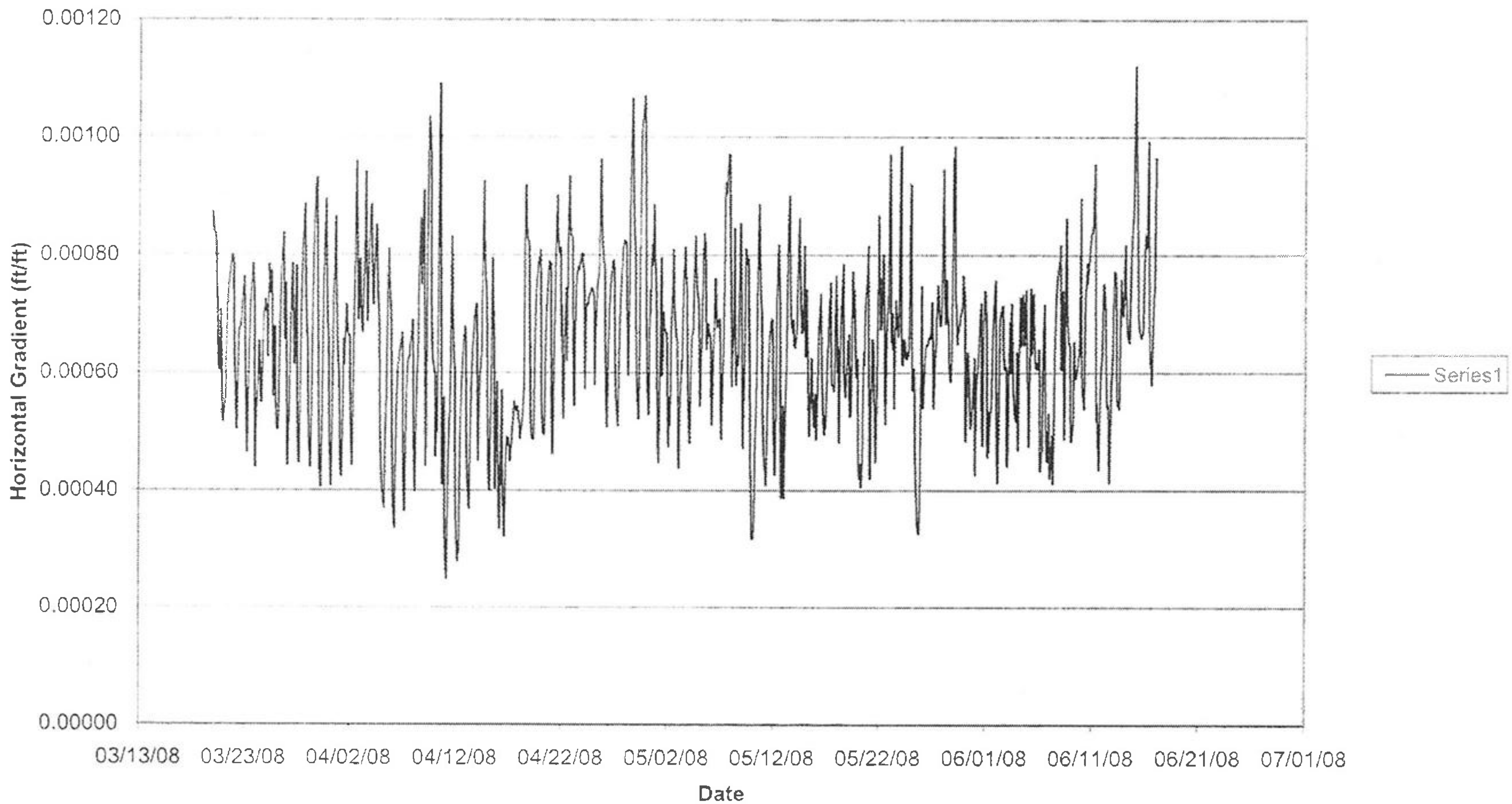
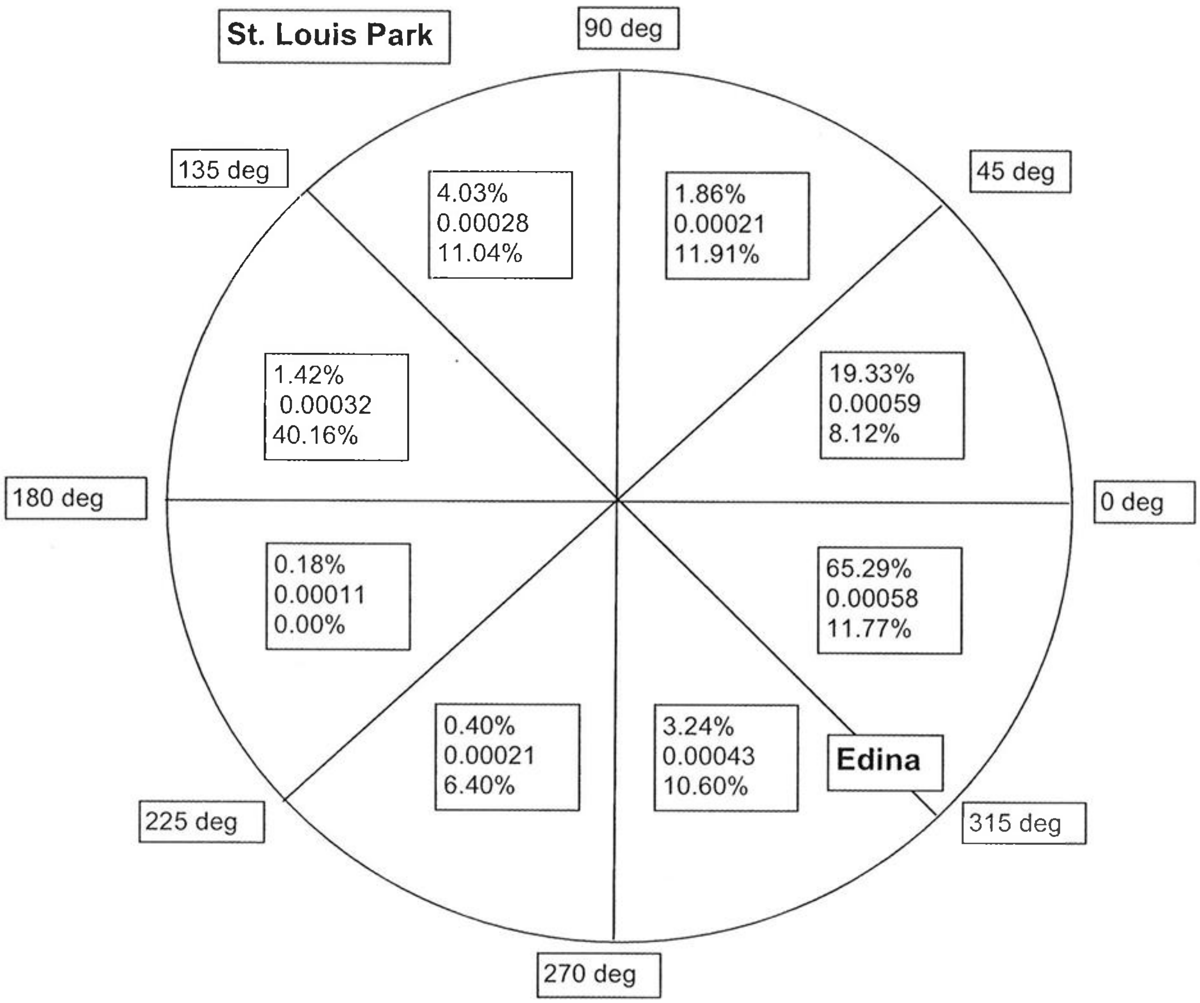


Figure 14A. OPCJ Gradient Direction (0 - 360 deg) and Magnitude (ft/ft) Summer 2008 (6/21/08 - 9/22/08)

AECOM Project 60137283 / 60145589



Note: The figure shows:

65.29% - percentage of the time during Summer 2008 groundwater flowed in a particular 45 deg direction
0.00058 - average gradient when groundwater flowed in that particular 45 deg direction range
11.77% - percentage of groundwater production from wells in that particular 45 deg direction range

90 deg - North
180 deg - West
270 deg - South
0 deg - East

Figure 15A. Changing OPCJ Gradient Direction - St. Louis Park / Edina - Summer 2008
AECOM Project No. 60137283 / 60145589

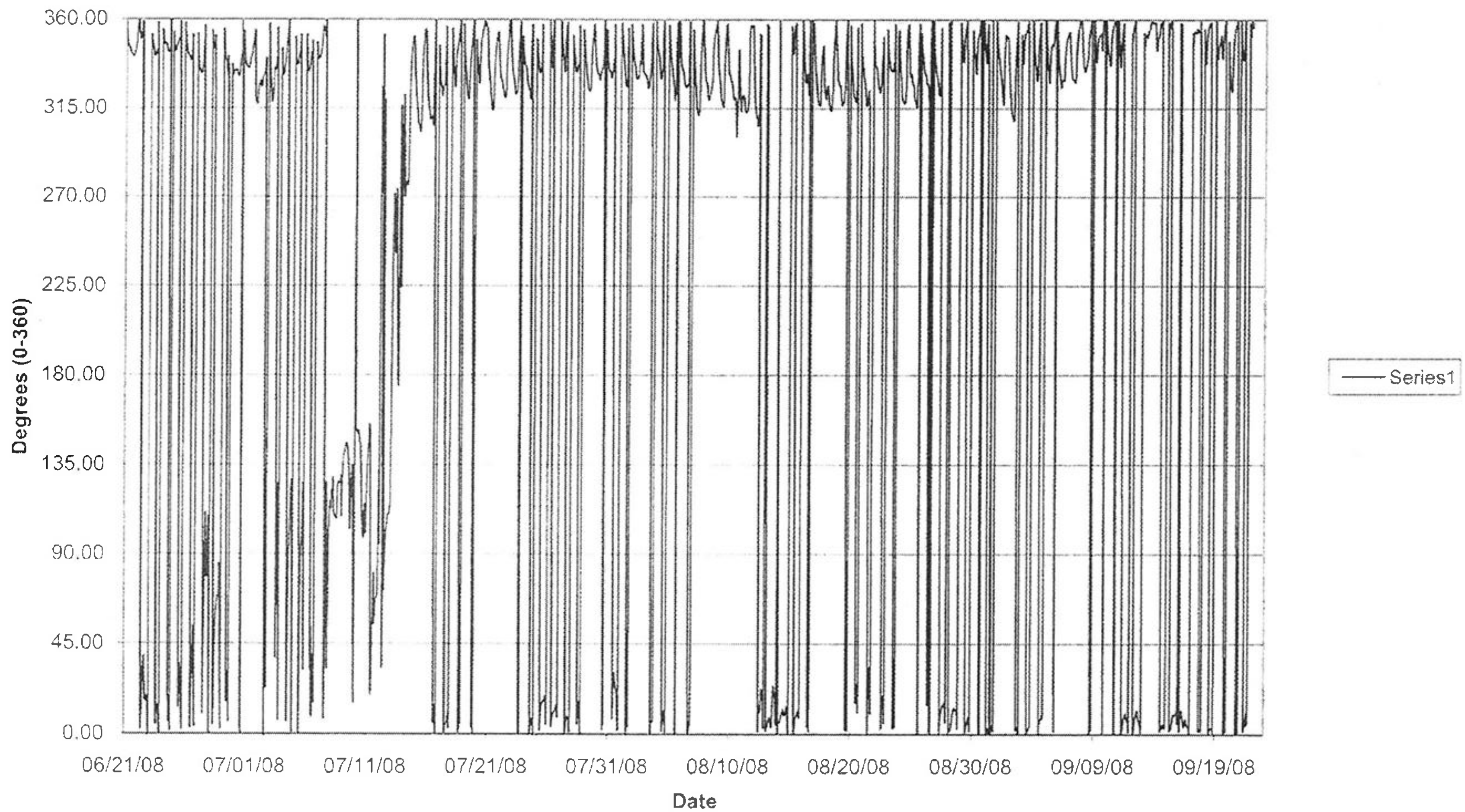


Figure 16A. Change in OPCJ Gradient Magnitude with Time - St. Louis Park / Edina - Summer 2008
AECOM Project No. 60137283 / 60145589

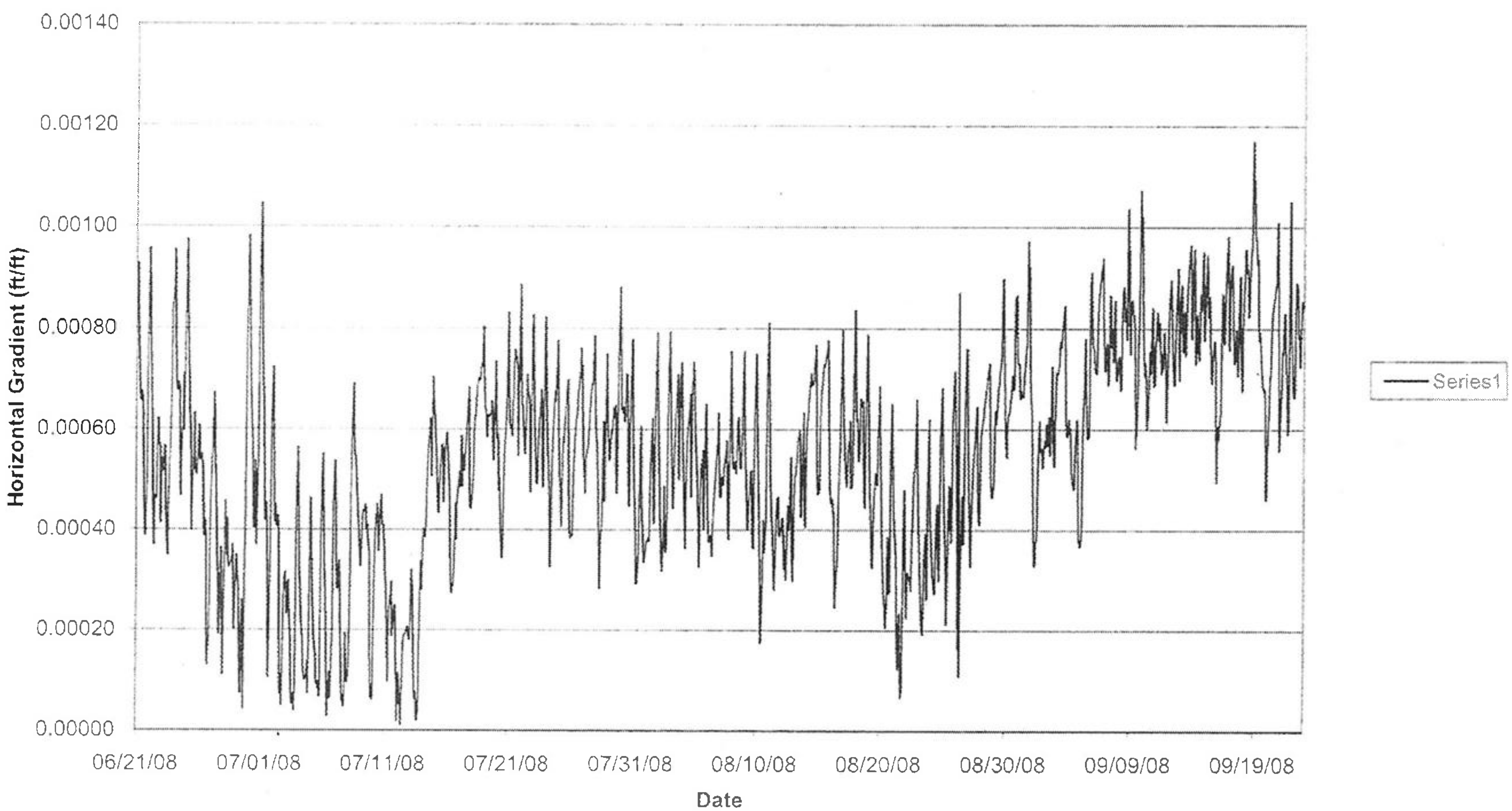
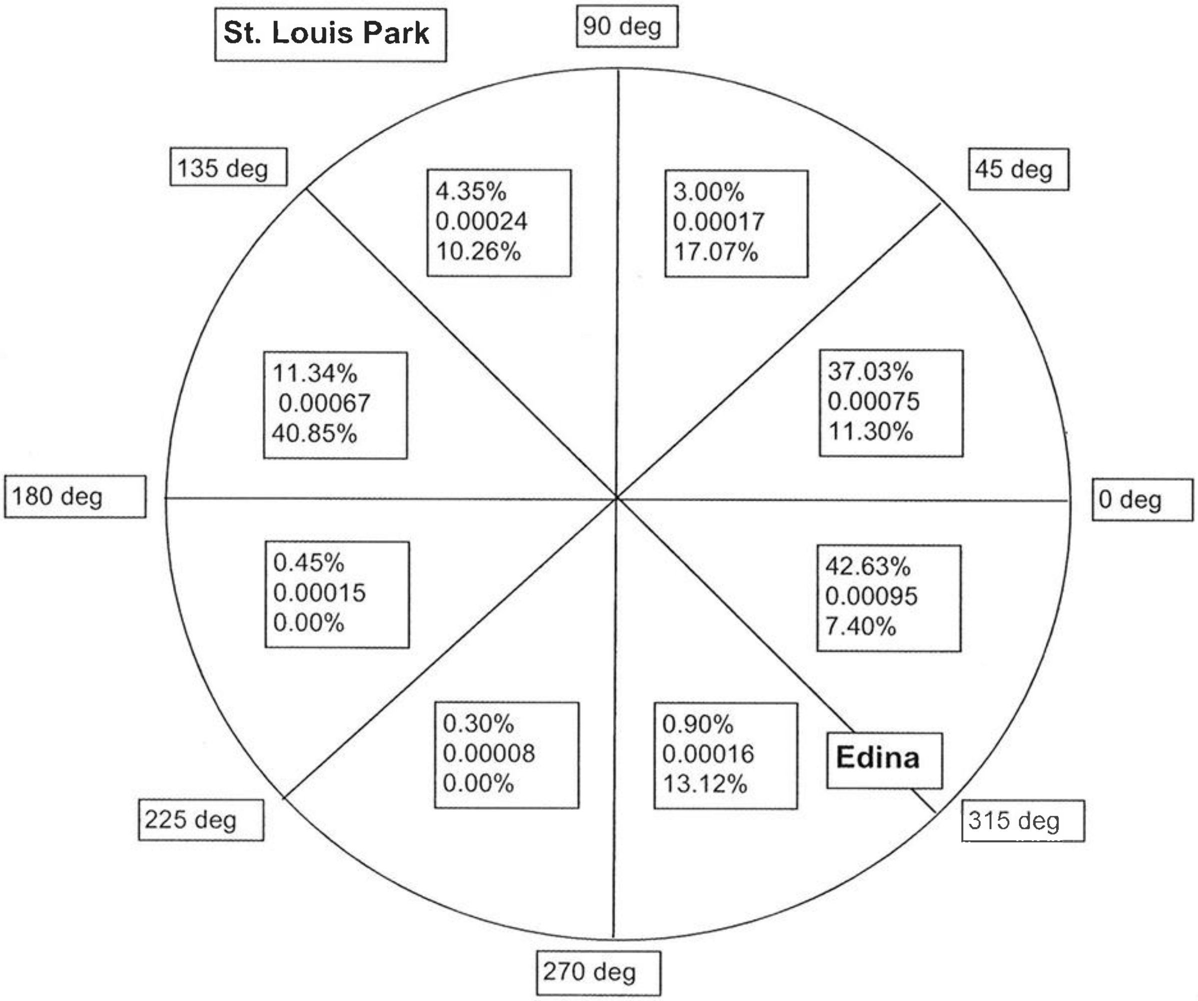


Figure 17A. OPCJ Gradient Direction (0 - 360 deg) and Magnitude (ft/ft)
Fall 2008 (9/23/08 - 12/15/08)

AECOM Project 60137283 / 60145589



Note: The figure shows:

42.63%	- percentage of the time during Fall 2008 groundwater flowed in a particular 45 deg direction
0.00095	- average gradient when groundwater flowed in that particular 45 deg direction range
7.40%	- percentage of groundwater production from wells in that particular 45 deg direction range
90 deg	- North
180 deg	- West
270 deg	- South
0 deg	- East

Figure 18A. Changing OPCJ Gradient Direction - St. Louis Park / Edina - Fall 2008
AECOM Project No. 60137283 / 60145589

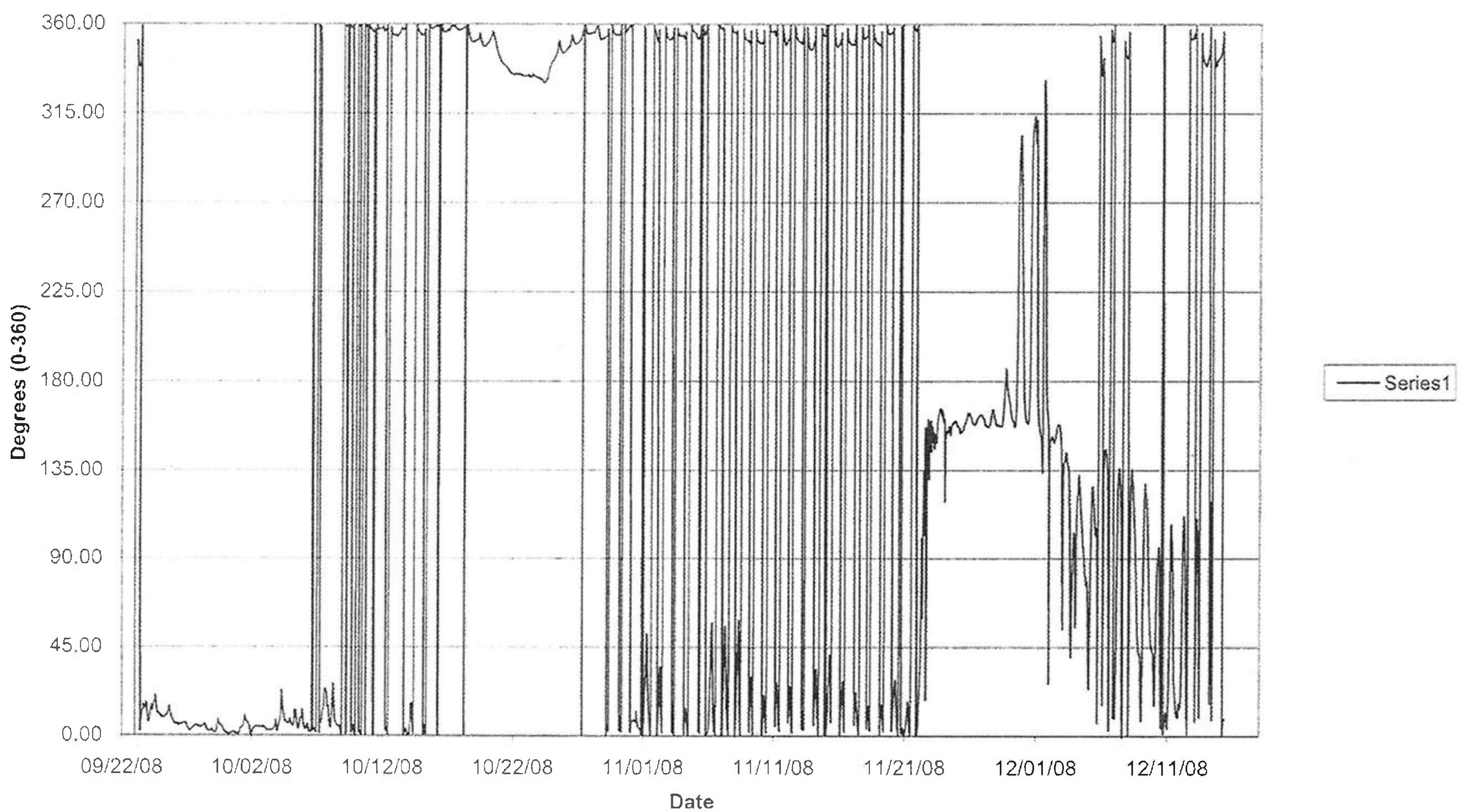


Figure 19A. Change in OPCJ Gradient Magnitude with Time - St. Louis Park / Edina - Fall 2008
AECOM Project No. 60137283 / 60145589

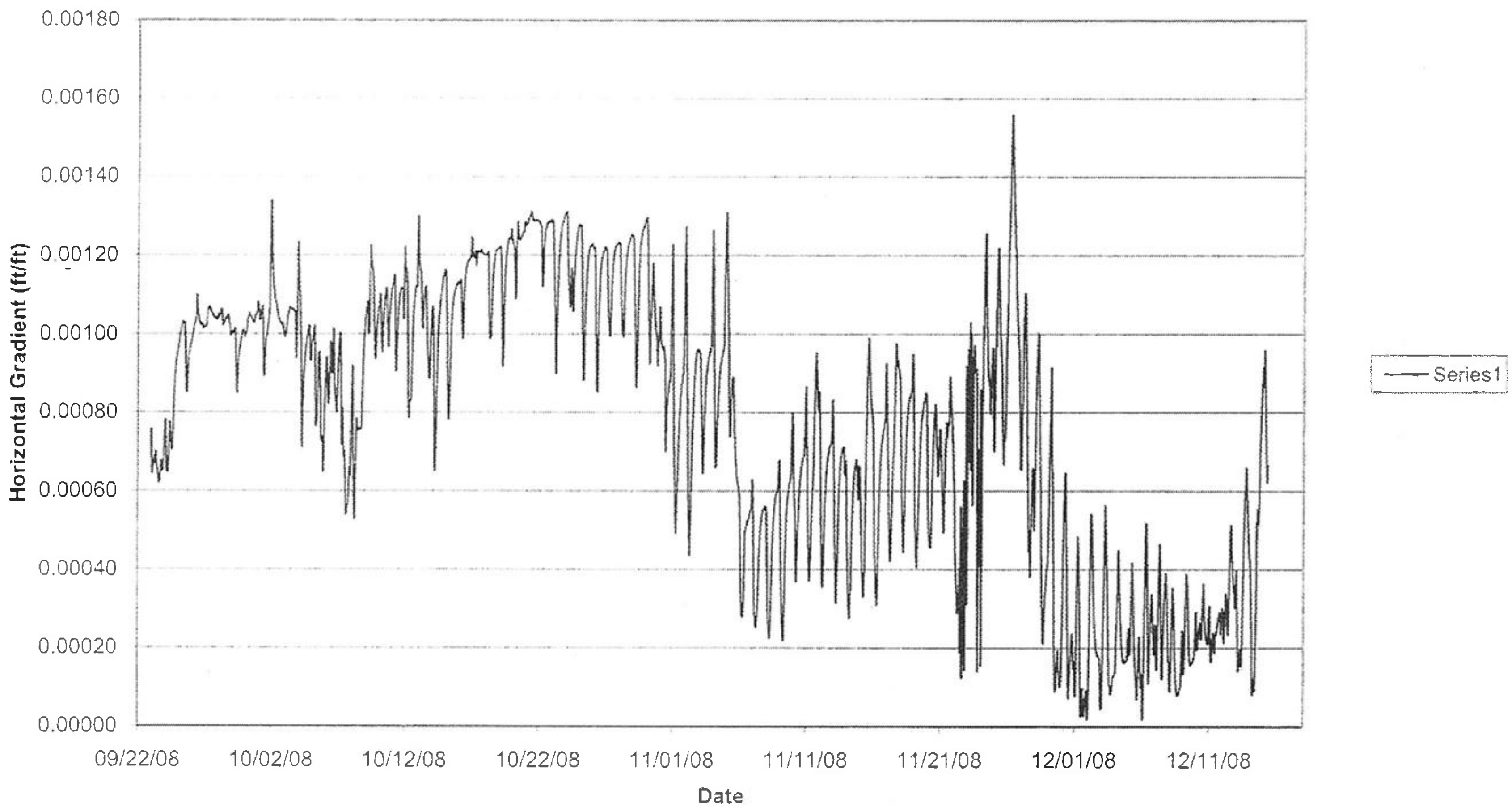
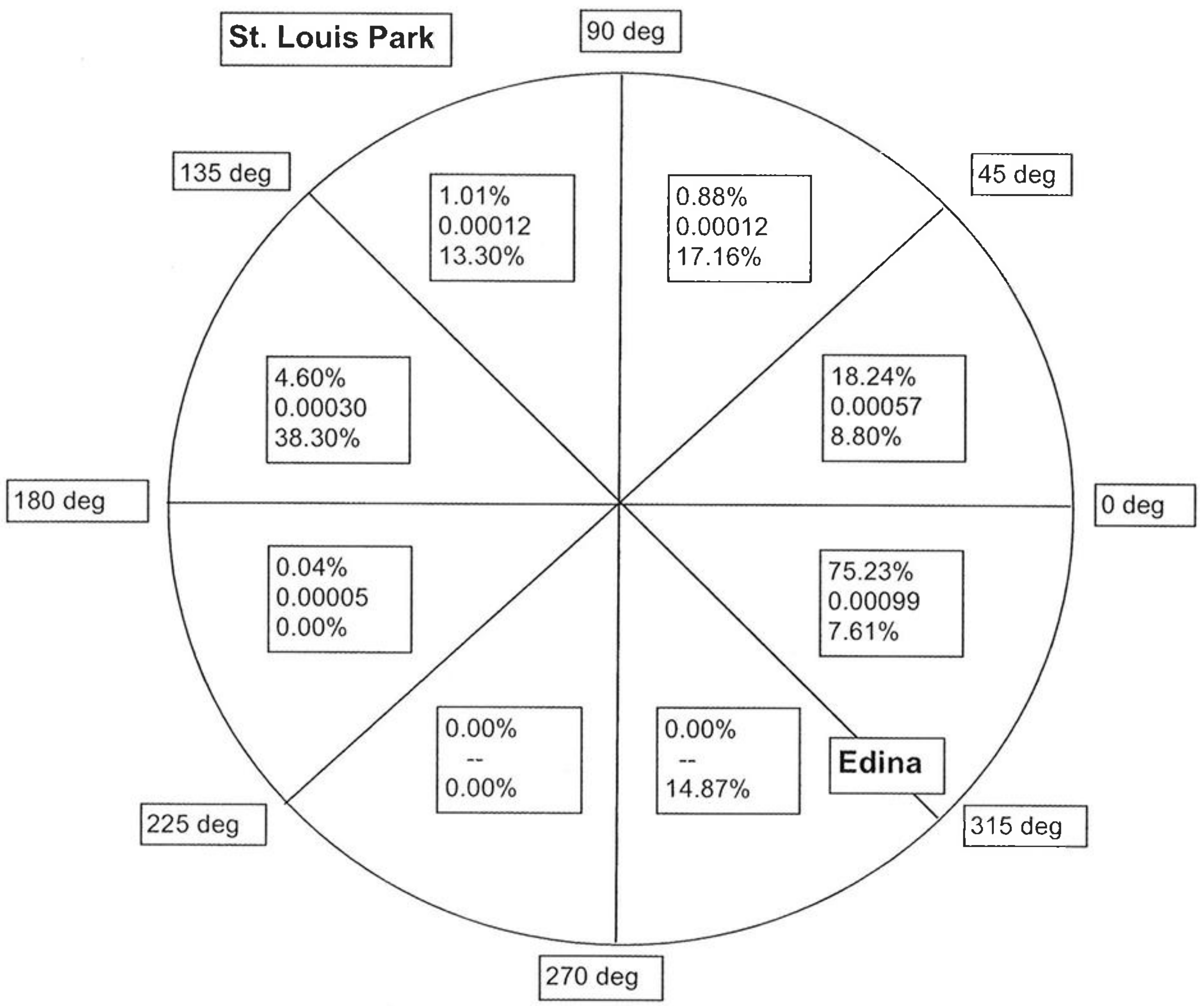


Figure 20A. OPCJ Gradient Direction (0 - 360 deg) and Magnitude (ft/ft) Winter 2009 (12/15/08 - 03/20/09)

AECOM Project 60137283 / 60145589



Note: The figure shows:

75.23%	- percentage of the time during Winter 2009 groundwater flowed in a particular 45 deg direction
0.00099	- average gradient when groundwater flowed in that particular 45 deg direction range
7.61%	- percentage of groundwater production from wells in that particular 45 deg direction range
90 deg	- North
180 deg	- West
270 deg	- South
0 deg	- East

Figure 21A. Changing OPCJ Gradient Direction - St. Louis Park / Edina - Winter 2009
AECOM Project No. 60137283 / 60145589

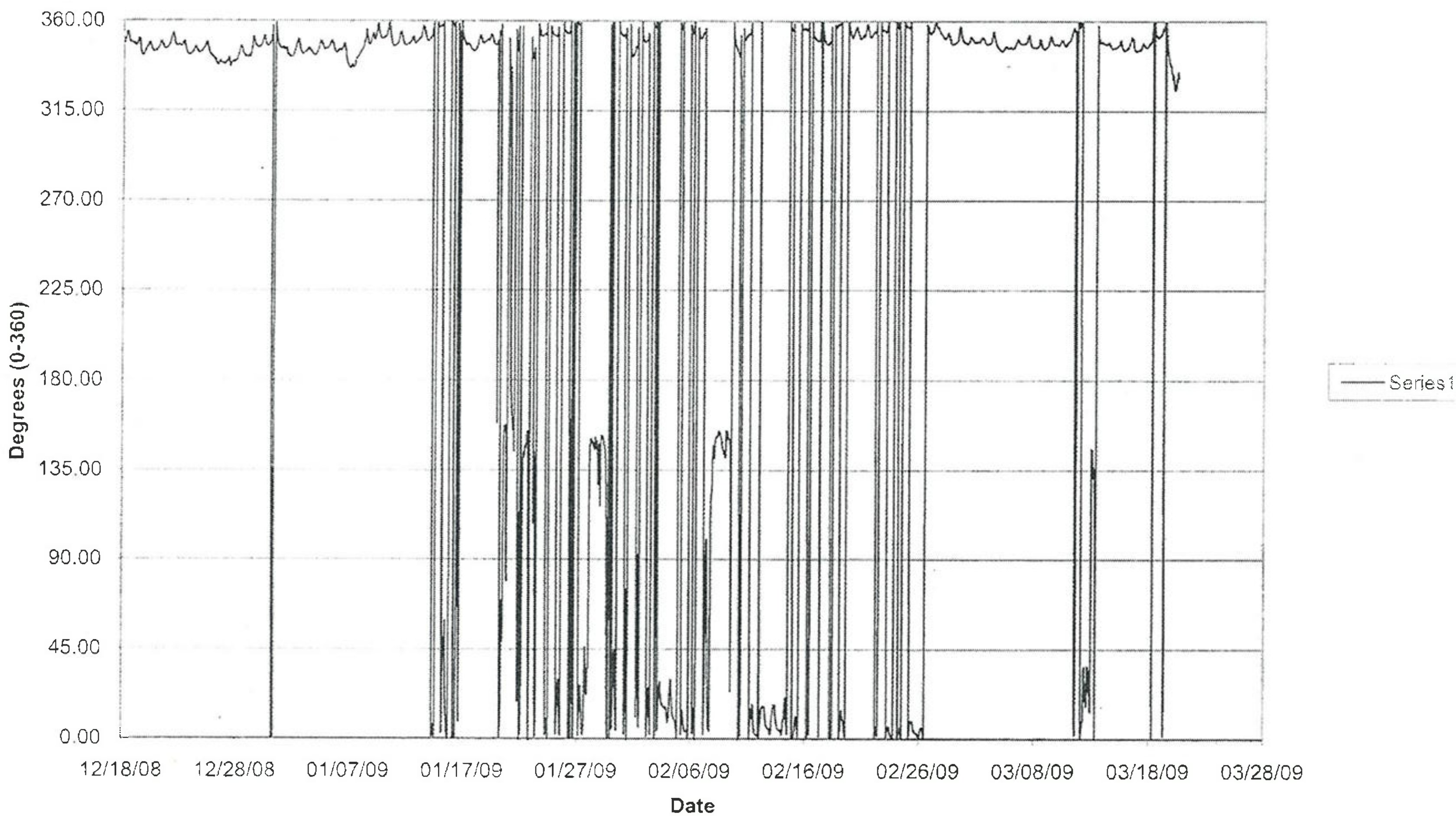


Figure 22A. Change in OPCJ Gradient Magnitude with Time - St. Louis Park / Edina - Winter 2009
AECOM Project No. 60137283 / 60145589

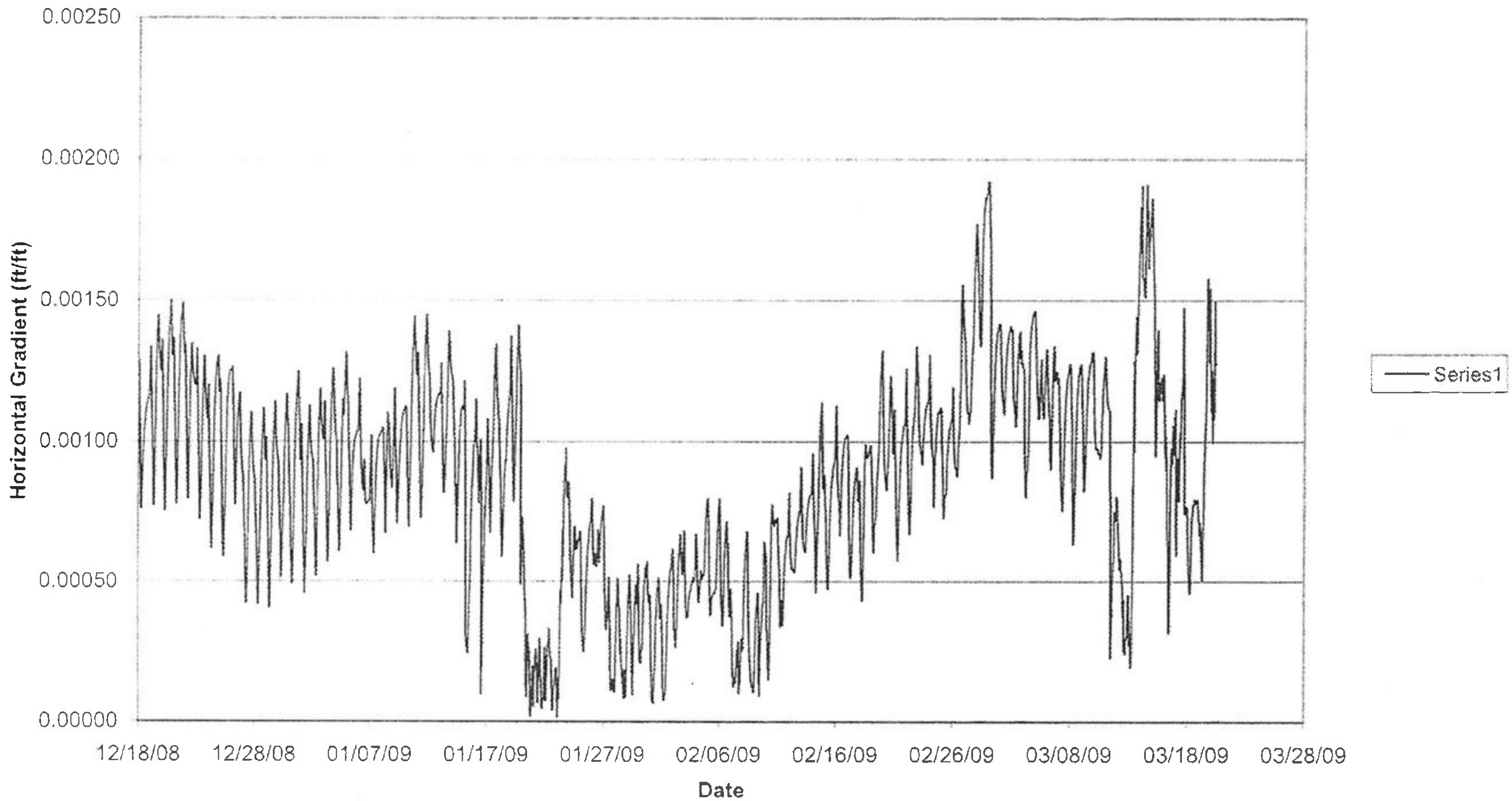
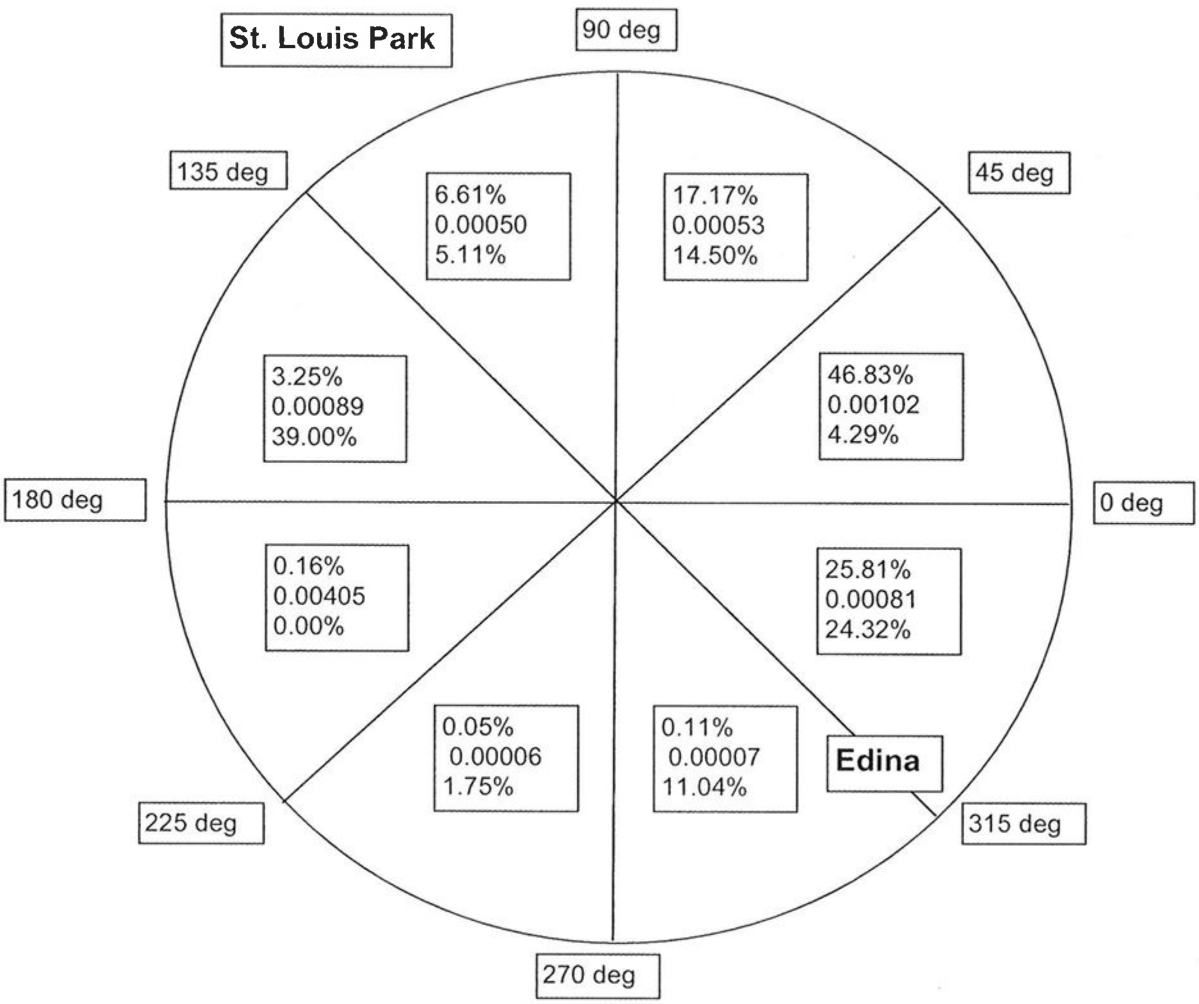


Figure 23A. OPCJ Gradient Direction (0 - 360 deg) and Magnitude (ft/ft)
Spring 2009 (03/20/09 - 06/06/09)

AECOM Project 60137283 / 60145589



Note: The figure shows:

75.23%	- percentage of the time during Spring 2009 groundwater flowed in a particular 45 deg direction
0.00099	- average gradient when groundwater flowed in that particular 45 deg direction range
7.61%	- percentage of groundwater production from wells in that particular 45 deg direction range
90 deg	- North
180 deg	- West
270 deg	- South
0 deg	- East

Figure 24A. Changing OPCJ Gradient Direction - St. Louis Park / Edina - Spring 2009
AECOM Project No. 60137283 / 60145589

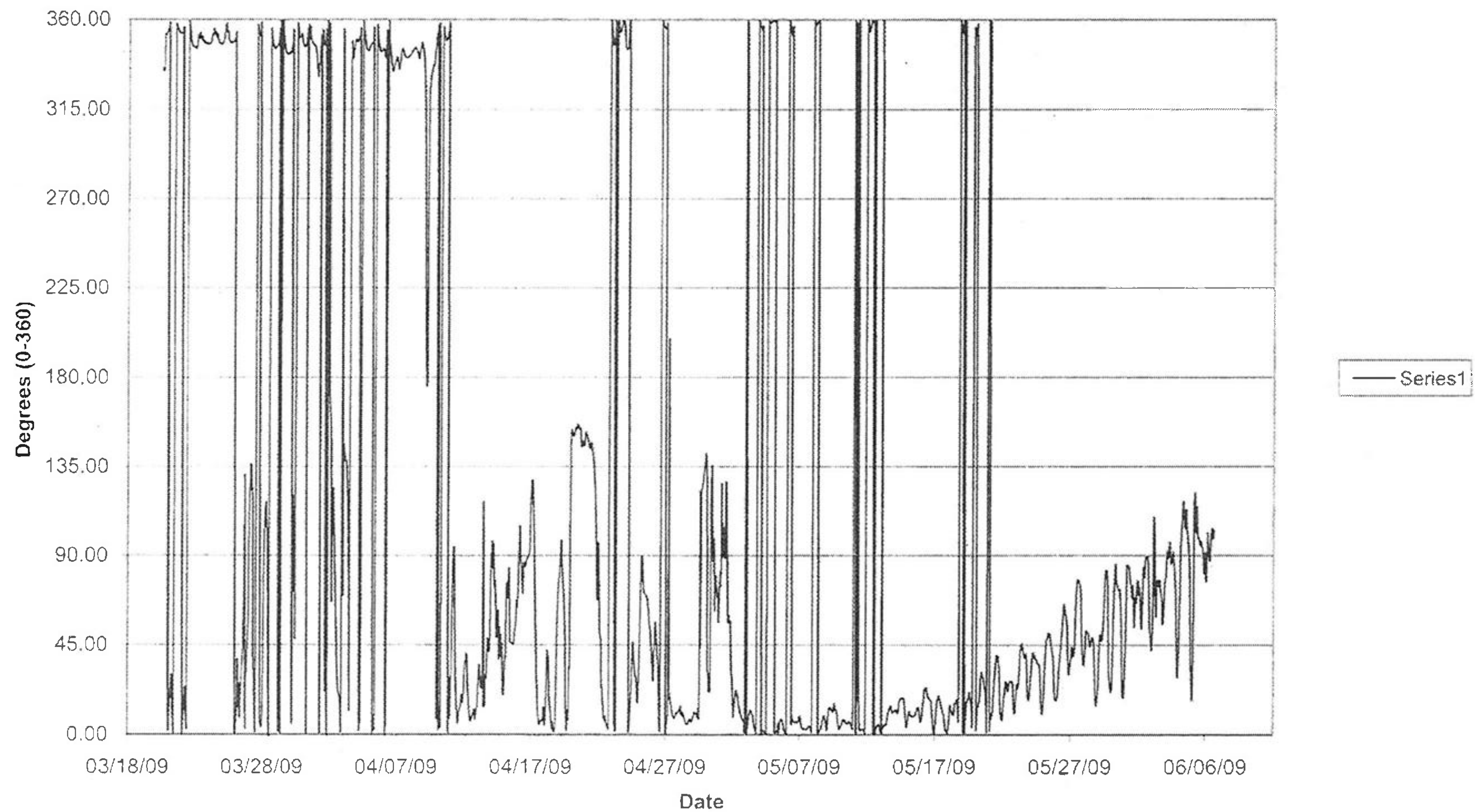


Figure 25A. Change in OPCJ Gradient Magnitude with Time - St. Louis Park / Edina - Spring 2009
AECOM Project No. 60137283 / 60145589

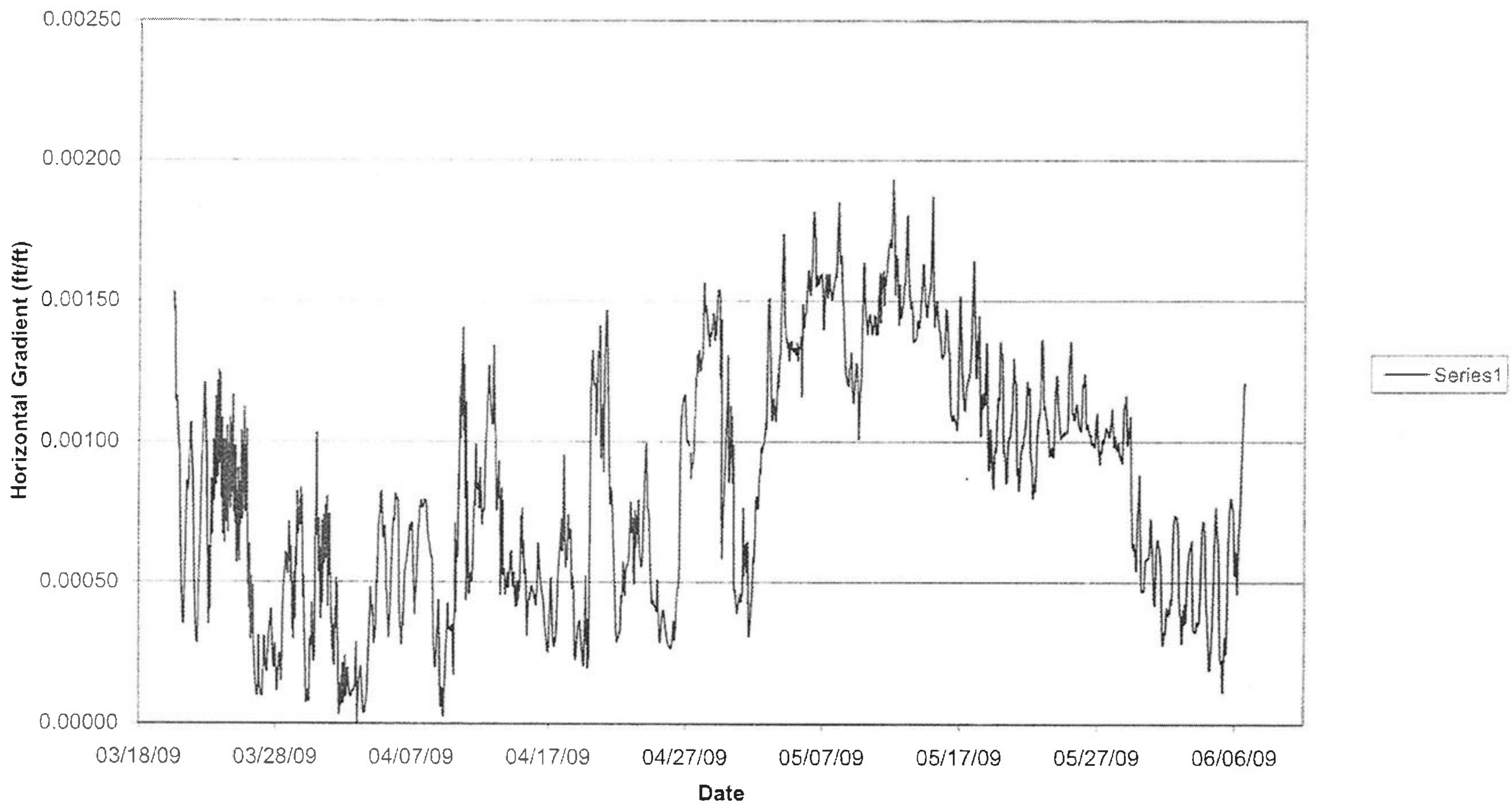
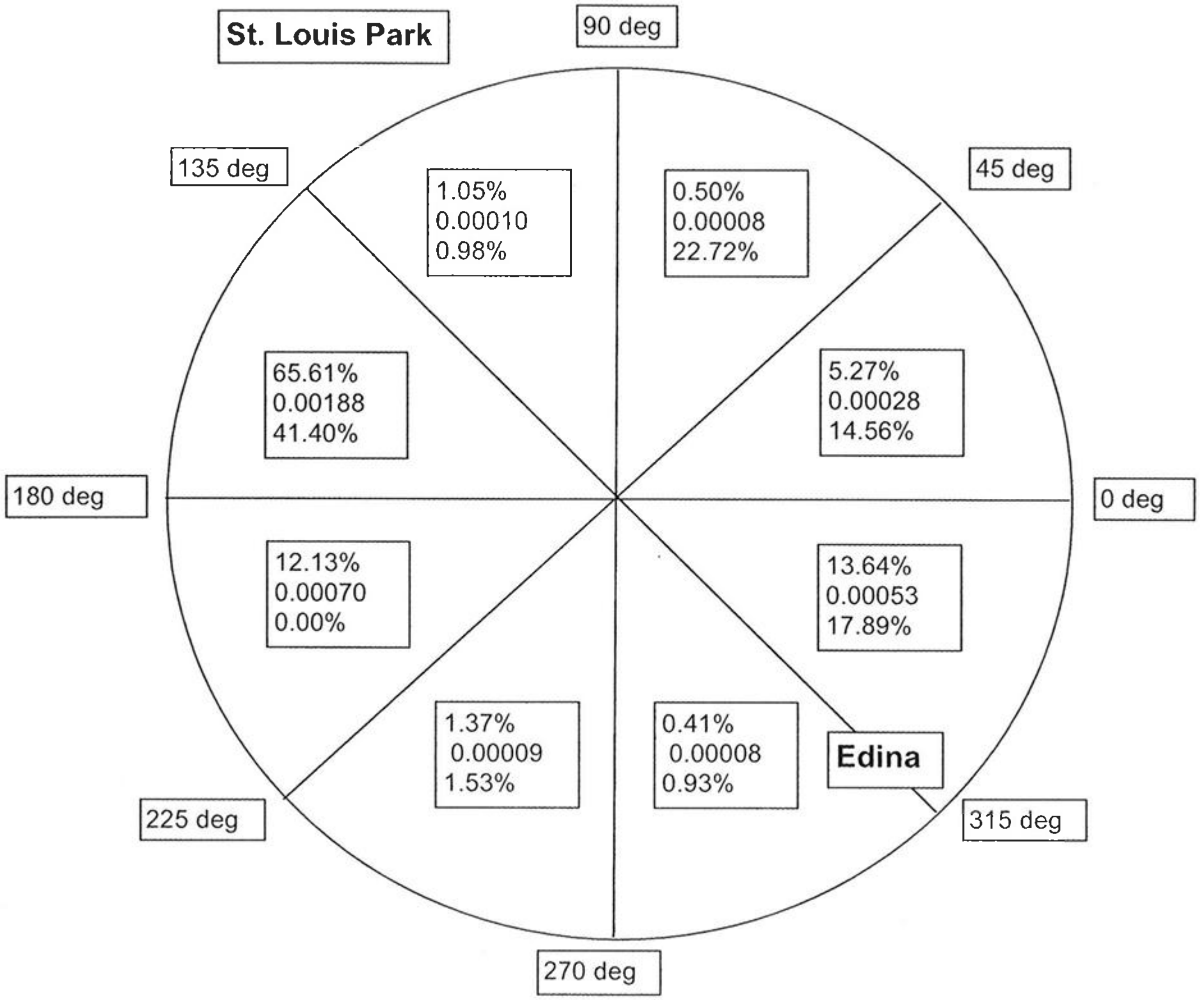


Figure 26A. OPCJ Gradient Direction (0 - 360 deg) and Magnitude (ft/ft)
Fall 2009 (09/22/09 - 12/21/09)

AECOM Project 60137283 / 60145589

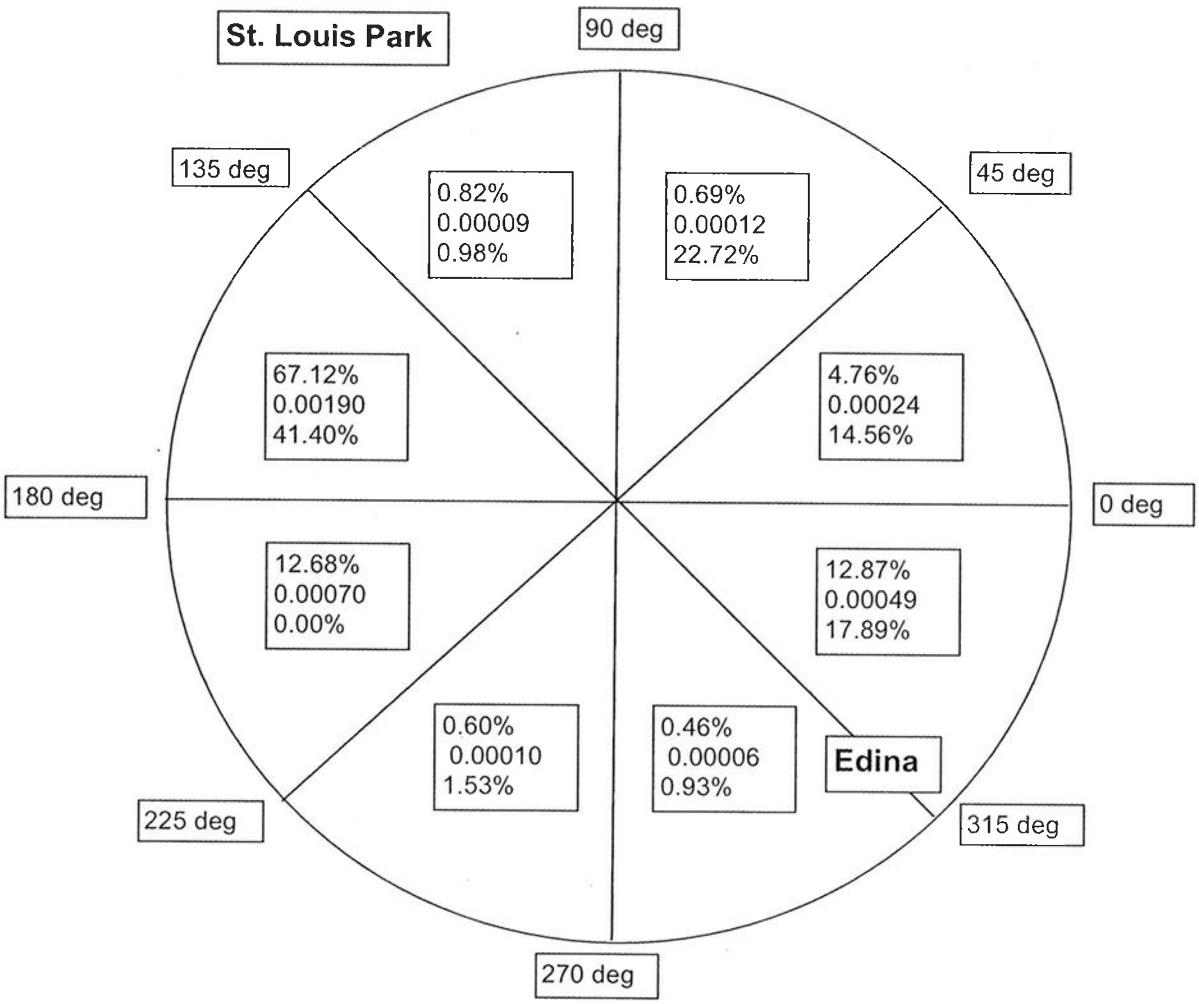


Note: The figure shows:

75.23%	- percentage of the time during Fall 2009 groundwater flowed in a particular 45 deg direction
0.00099	- average gradient when groundwater flowed in that particular 45 deg direction range
7.61%	- percentage of groundwater production from wells in that particular 45 deg direction range
90 deg	- North
180 deg	- West
270 deg	- South
0 deg	- East

Figure 26A'. OPCJ Gradient Direction (0 - 360 deg) and Magnitude (ft/ft)
Fall 2009 (09/22/09 - 12/21/09)

AECOM Project 60137283 / 60145589



Note: The figure shows:

75.23%	- percentage of the time during Fall 2009 groundwater flowed in a particular 45 deg direction
0.00099	- average gradient when groundwater flowed in that particular 45 deg direction range
7.61%	- percentage of groundwater production from wells in that particular 45 deg direction range
90 deg	- North
180 deg	- West
270 deg	- South
0 deg	- East

Figure 27A. Changing OPCJ Gradient Direction - St. Louis Park / Edina - Fall 2009
AECOM Project No. 60137283 / 60145589

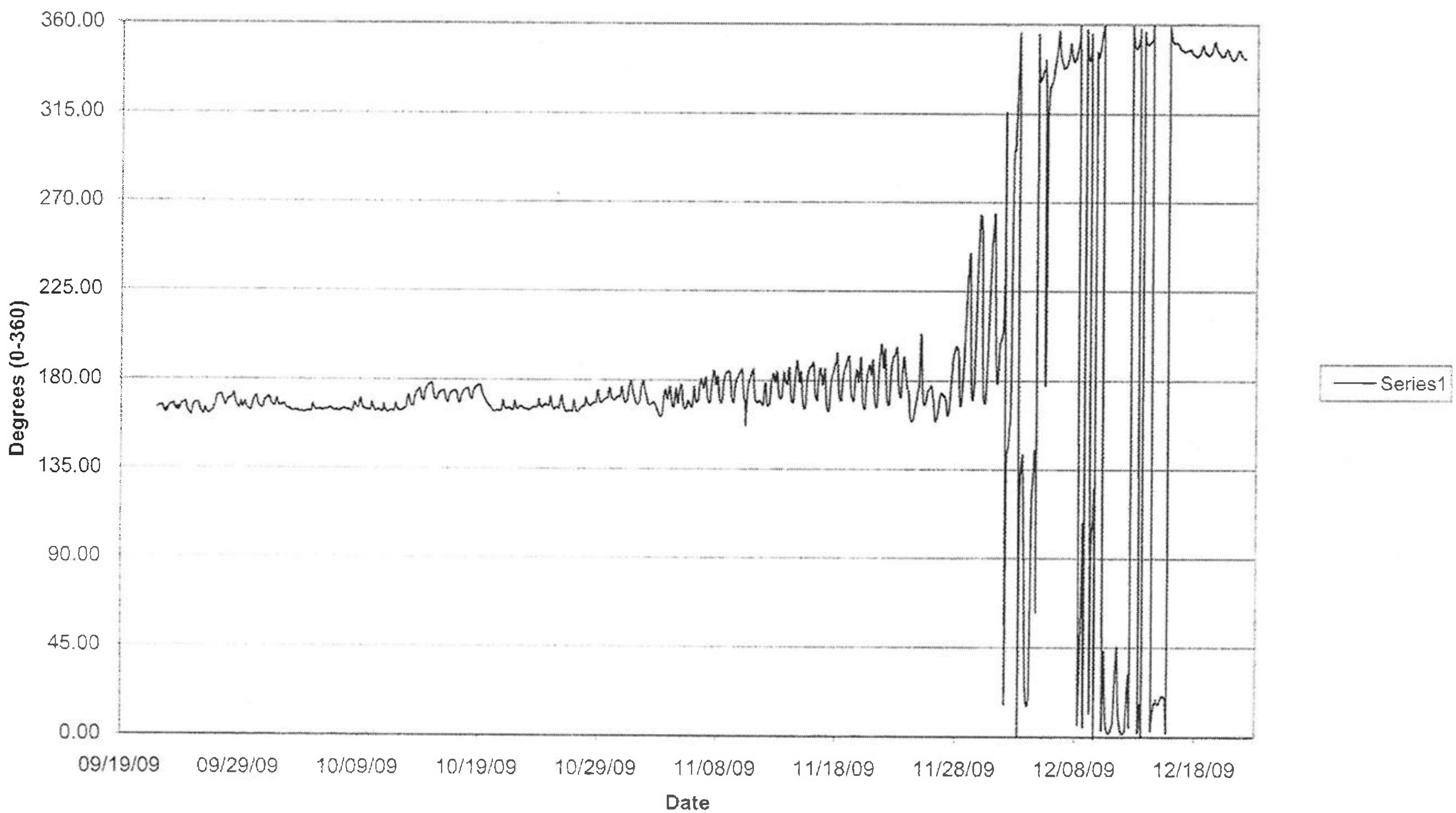


Figure 27A'. Changing OPCJ Gradient Direction - St. Louis Park / Edina - Fall 2009
AECOM Project No. 60137283 / 60145589

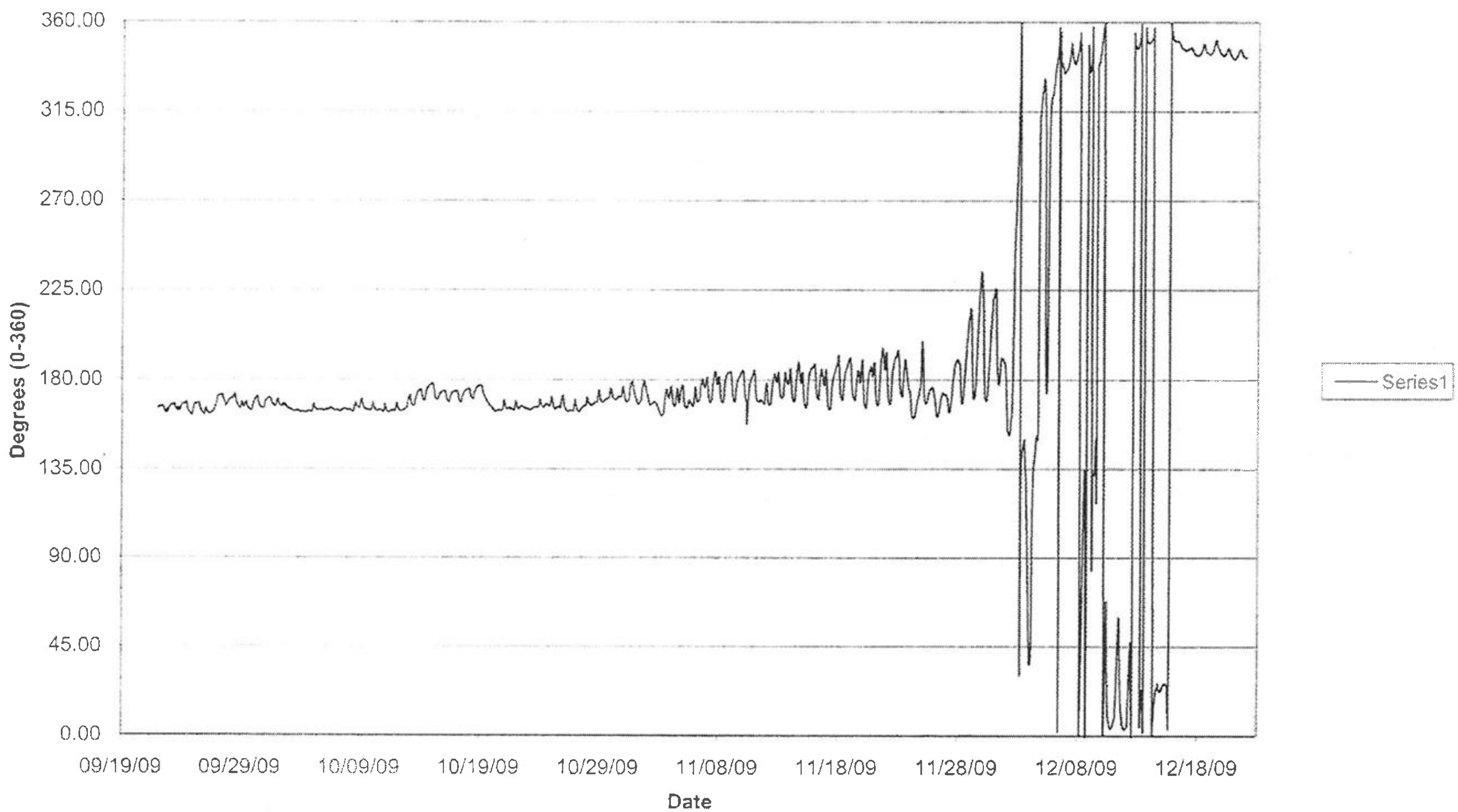


Figure 28A. Change in OPCJ Gradient Magnitude with Time - St. Louis Park / Edina - Fall 2009
AECOM Project No. 60137283 / 60145589

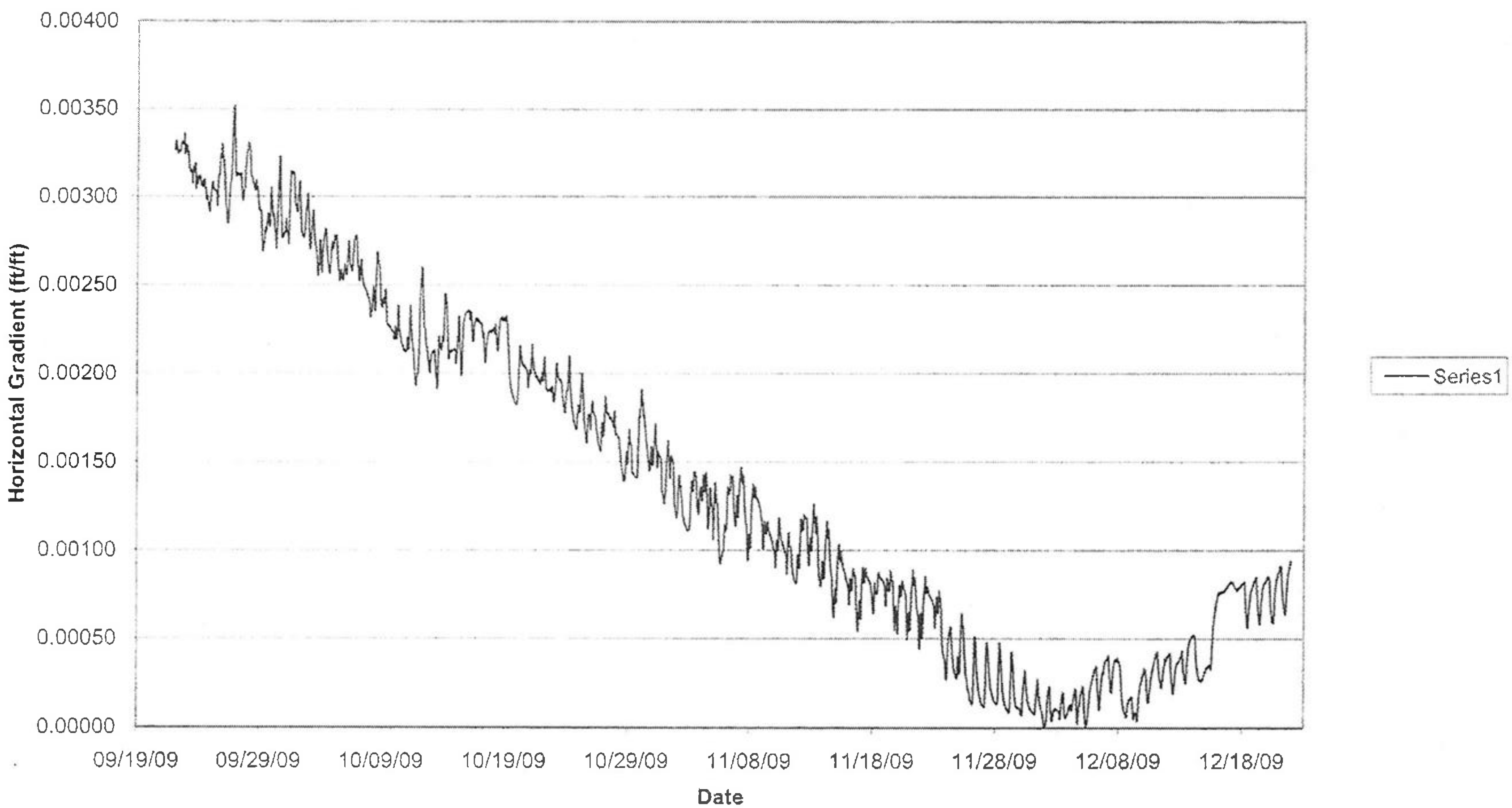
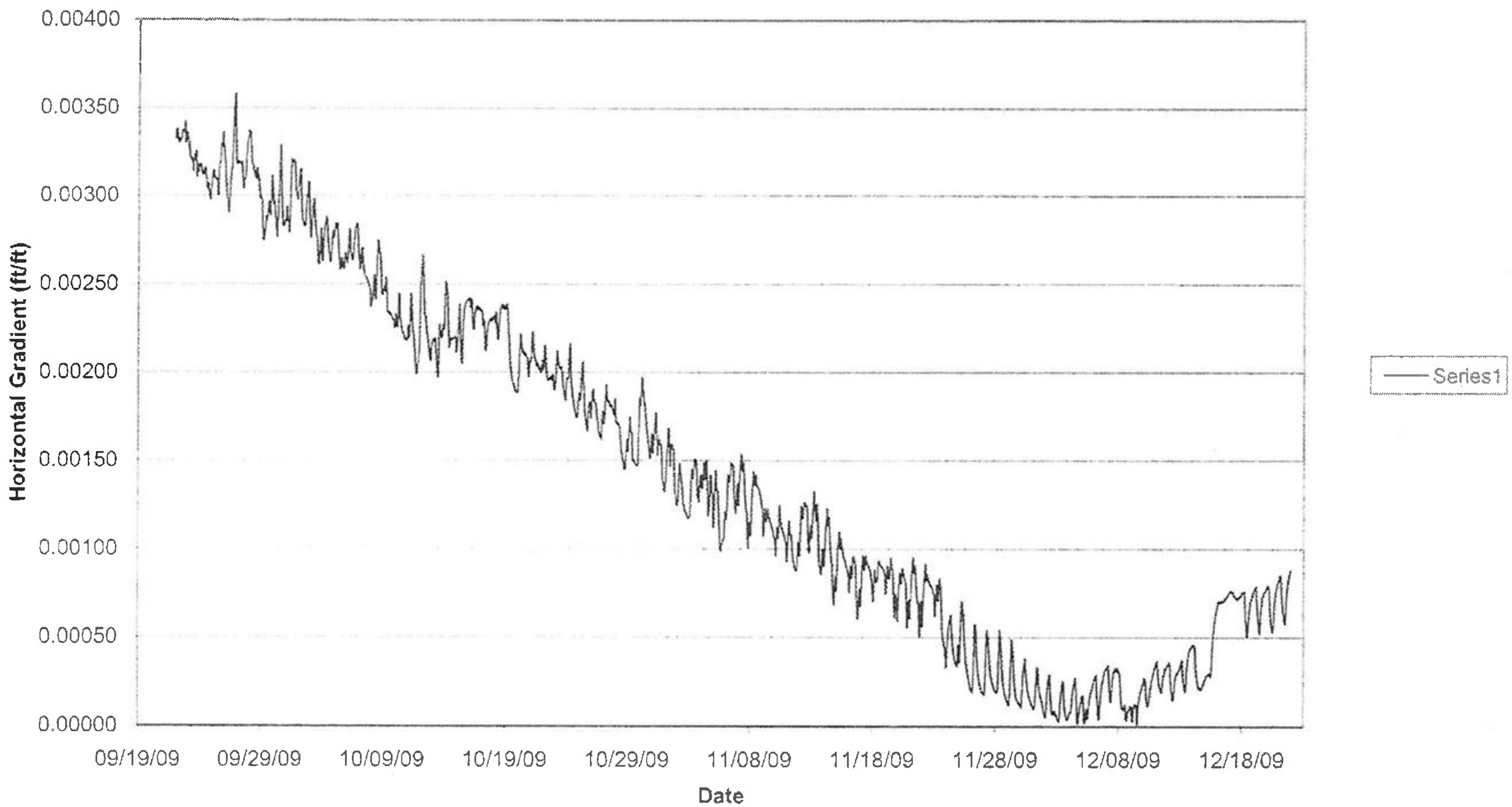


Figure 28A'. Change in OPCJ Gradient Magnitude with Time - St. Louis Park / Edina - Fall 2009
AECOM Project No. 60137283 / 60145589



Appendix B

Comparison of Water Levels Measured in Municipal Wells and Monitoring Wells in January 2010

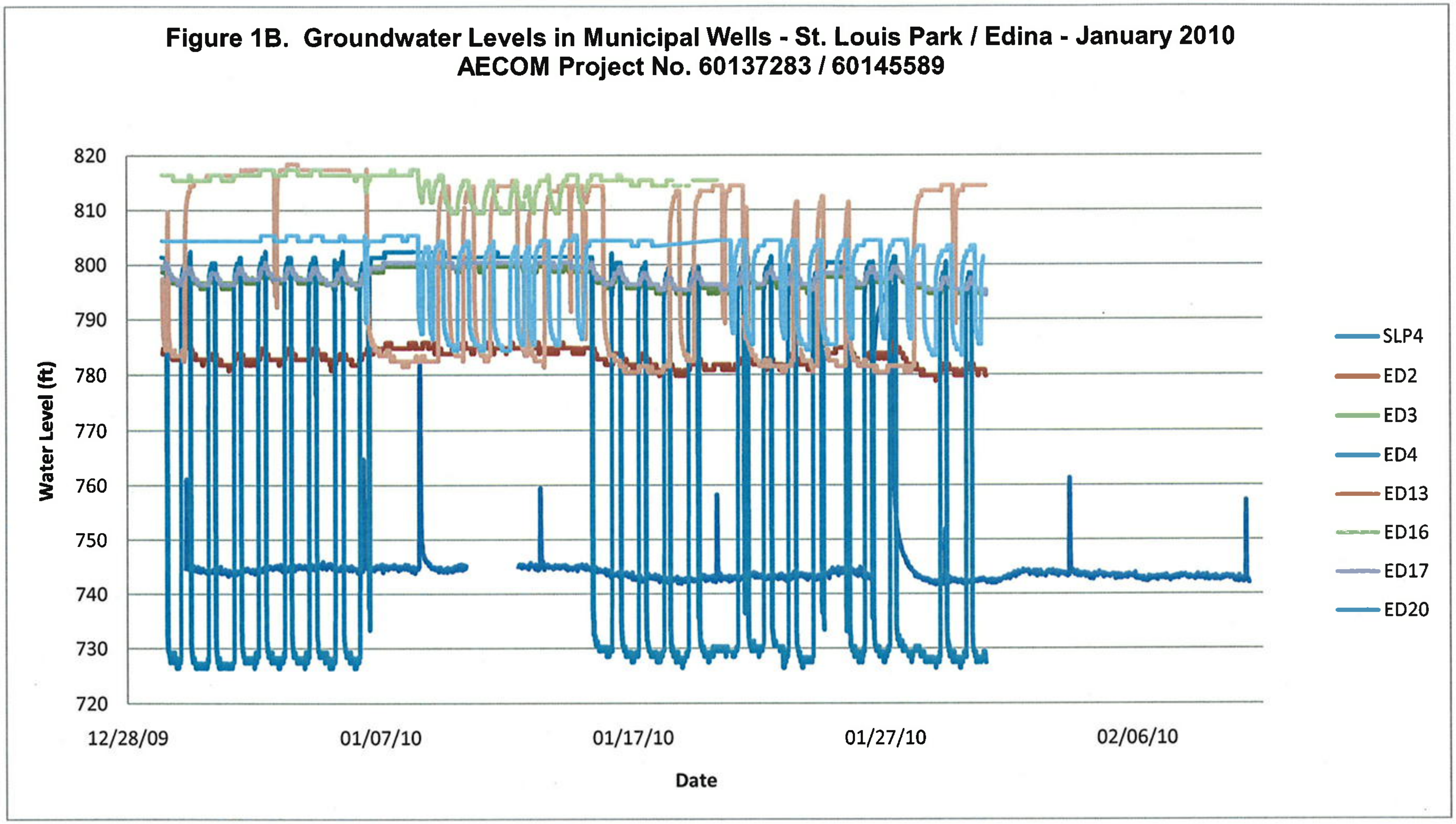
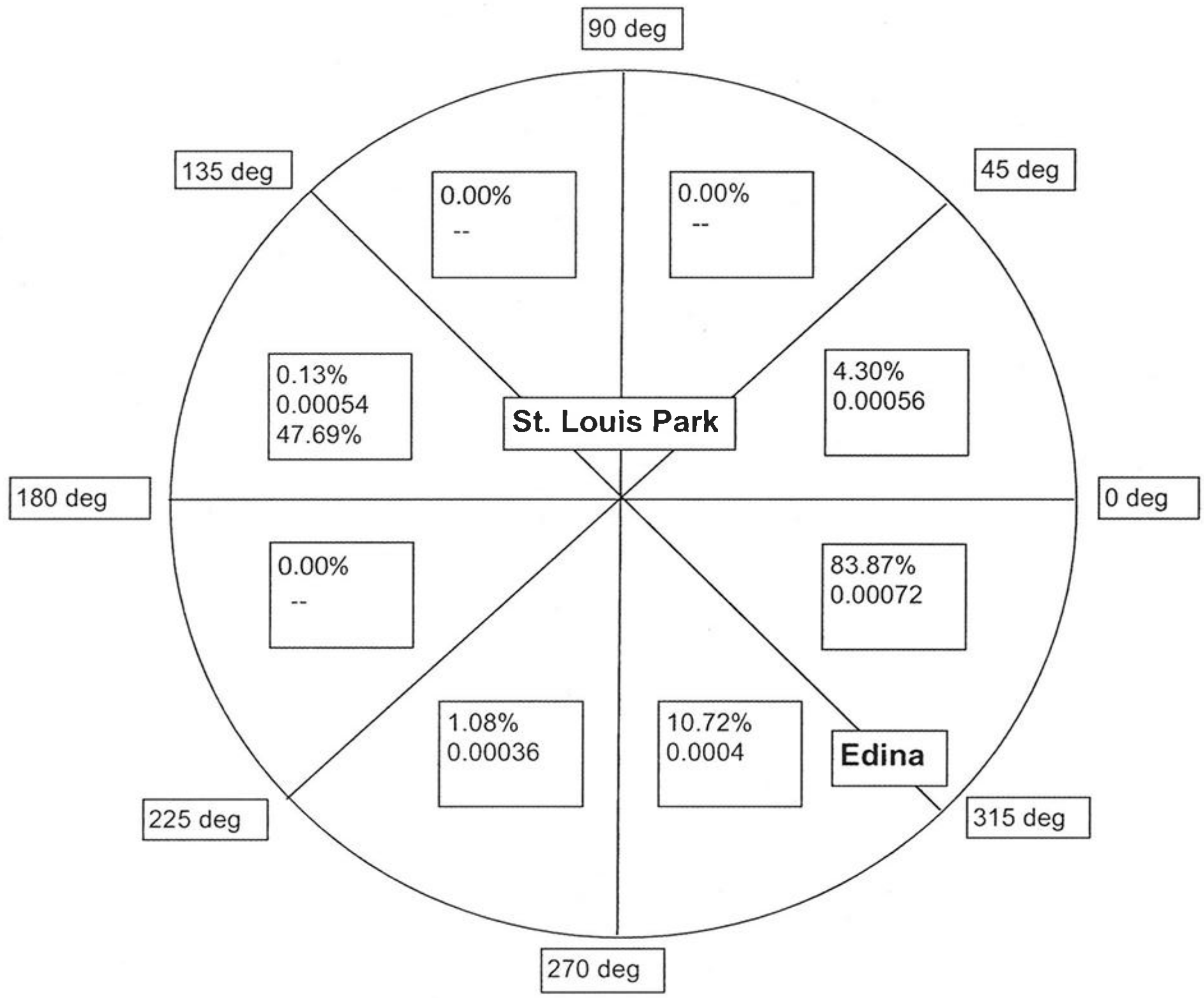


Figure 1B. Groundwater Levels in Municipal Wells - St. Louis Park / Edina - January 2010
AECOM Project No. 60137283 / 60145589
Water Level (ft)
820
810
800
790
780
770
760
750
740
730
720
12/28/09
01/07/10
01/17/10
01/27/10
02/06/10
Date
SLP4
ED2
ED3
ED4
ED13
ED16
ED17
ED20

Figure 2B. OPCJ Gradient Direction (0 - 360 deg) and Magnitude (ft/ft)
January 2010 (01/01/10 - 01/31/10)

AECOM Project 60137283 / 60145589



Note: The figure shows:

83.87%	- percentage of the time during Jan. 2010 groundwater flowed in a particular 45 deg direction range
0.00072	- average gradient when groundwater flowed in that particular 45 deg direction range
90 deg	- North
180 deg	- West
270 deg	- South

Figure 3B. Changing OPCJ Gradient Direction - St. Louis Park / Edina - January 2010
AECOM Project No. 60137283 / 60145589

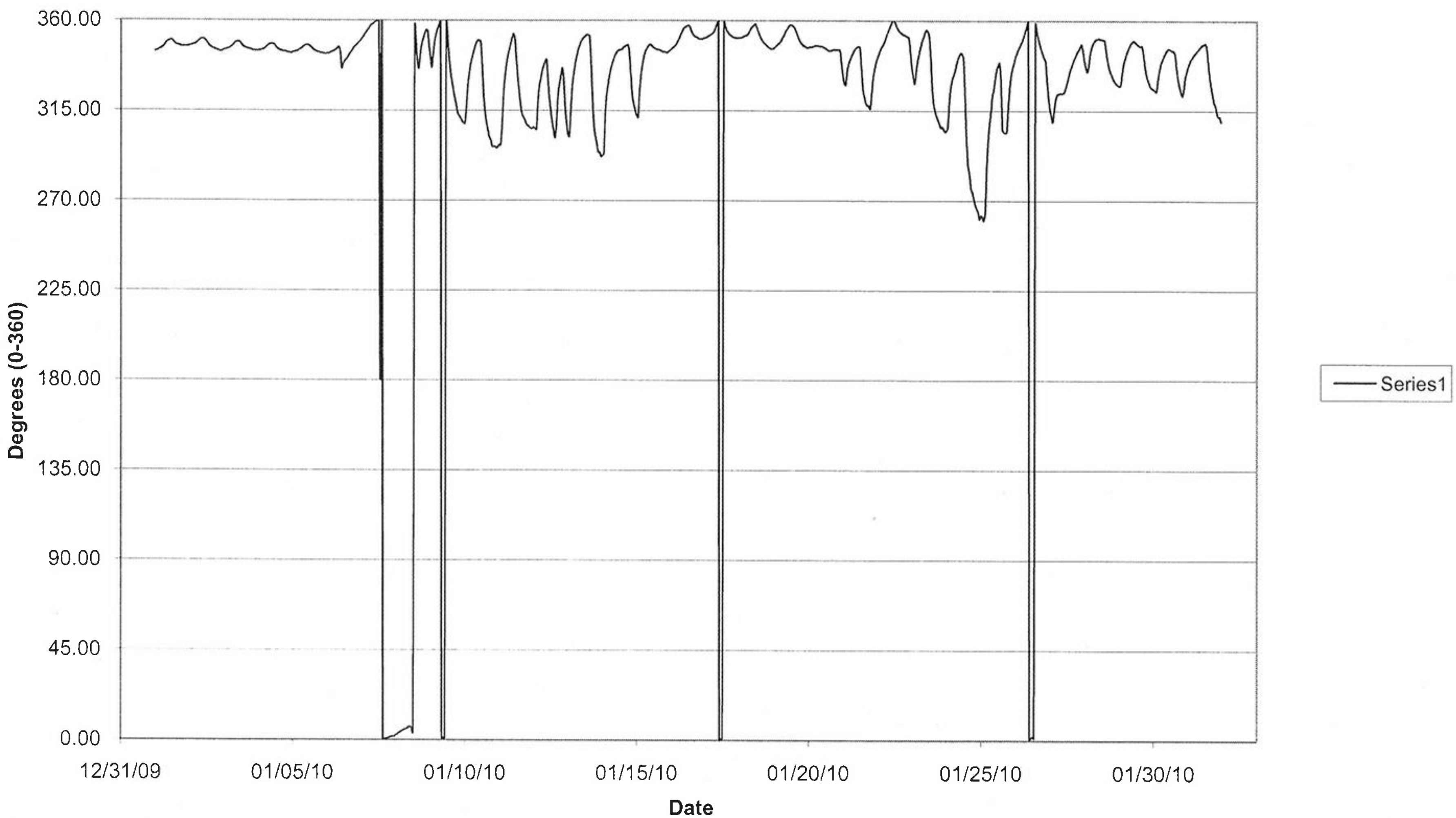


Figure 4B. Change in OPCJ Gradient Magnitude with Time - St. Louis Park / Edina - January 2010
AECOM Project No. 60137283 / 60145589

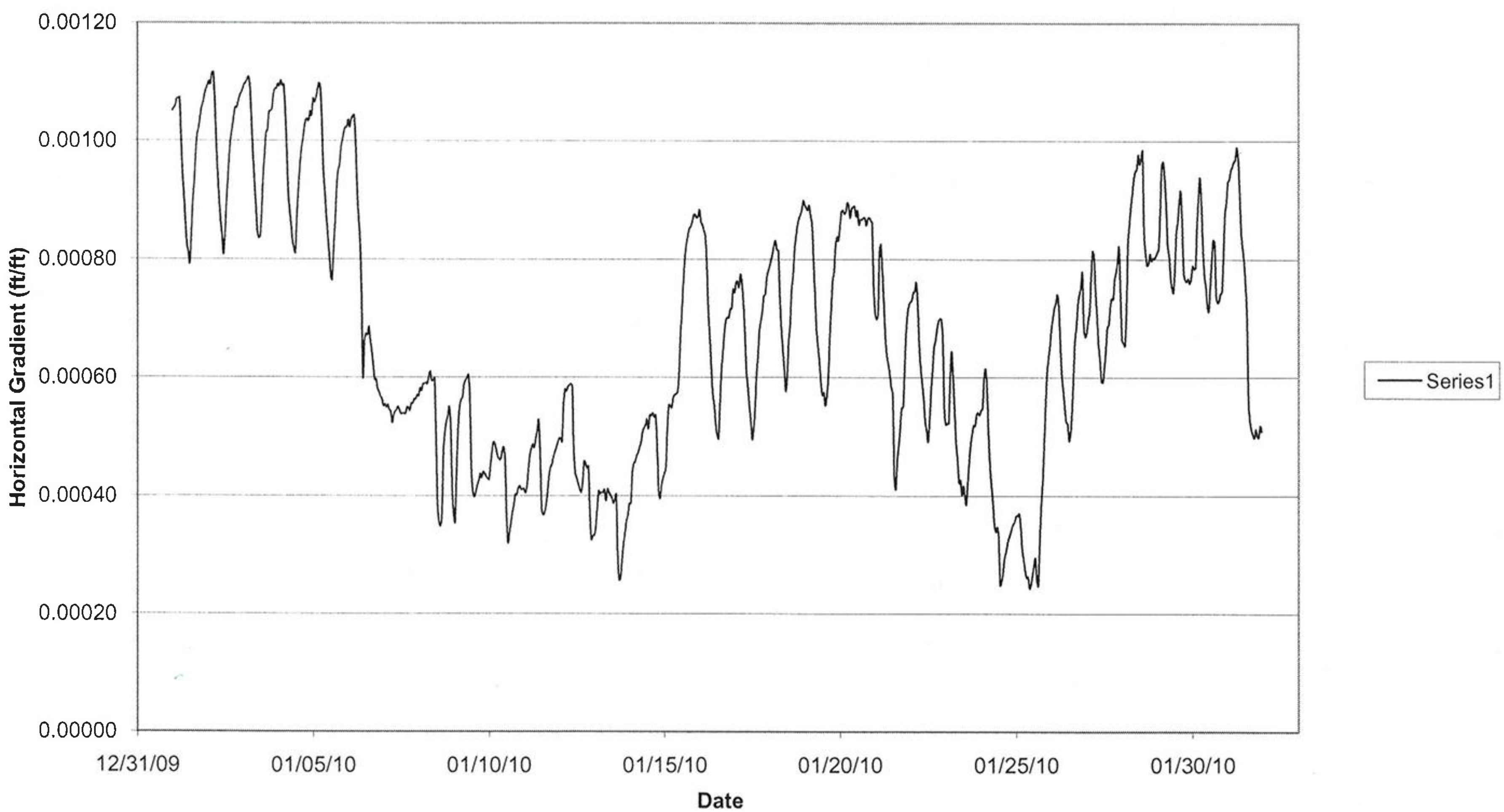


Figure 5B a. Changing OPCJ Gradient Direction - St. Louis Park / Edina - January 2010
AECOM Project No. 60137283 / 60145589

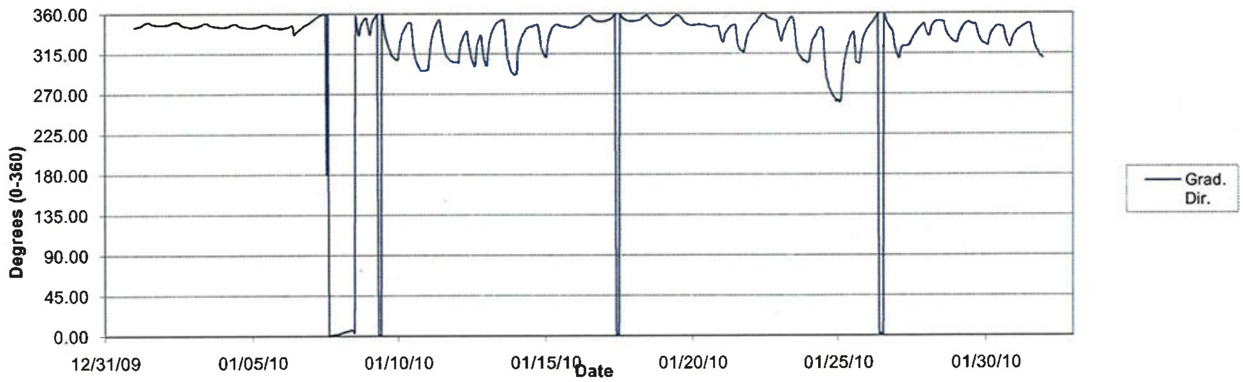


Figure 5B b. Water Levels in Selected Edina and St. Louis Park Municiapl Wells - January 2010
AECOM Project No. 60137283 / 60145589

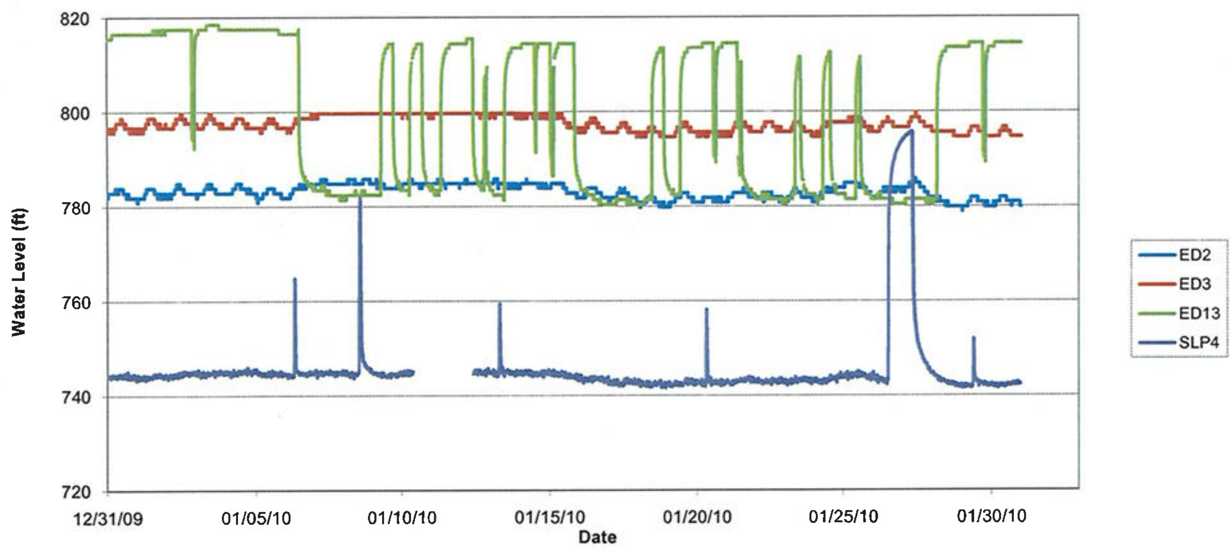


Figure 5B c. Water Levels in Selected Edina Municiapl Wells - January 2010
AECOM Project No. 60137283 / 60145589

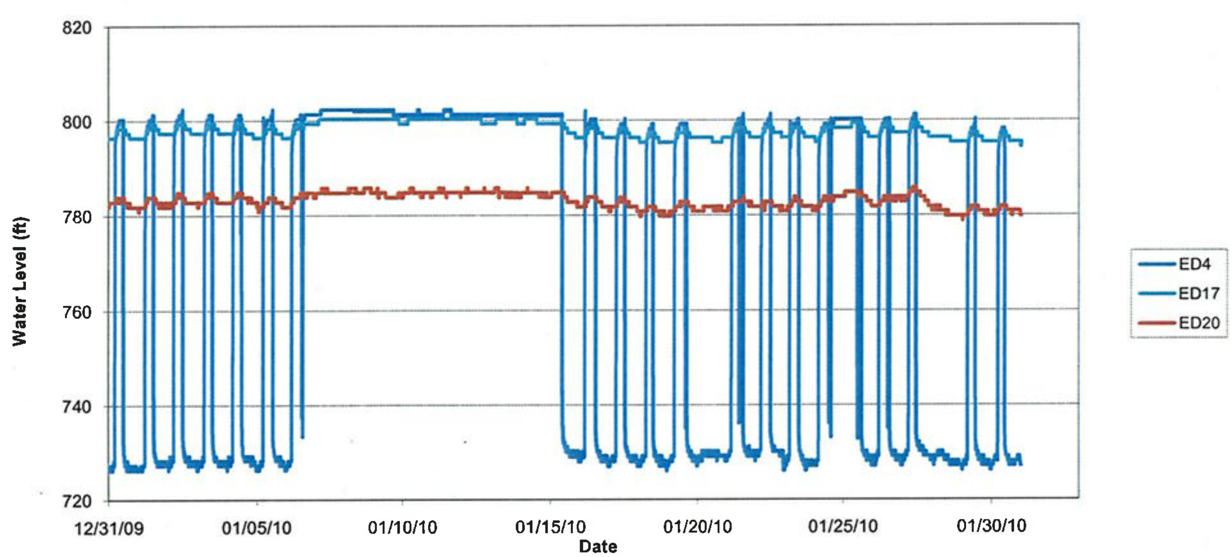
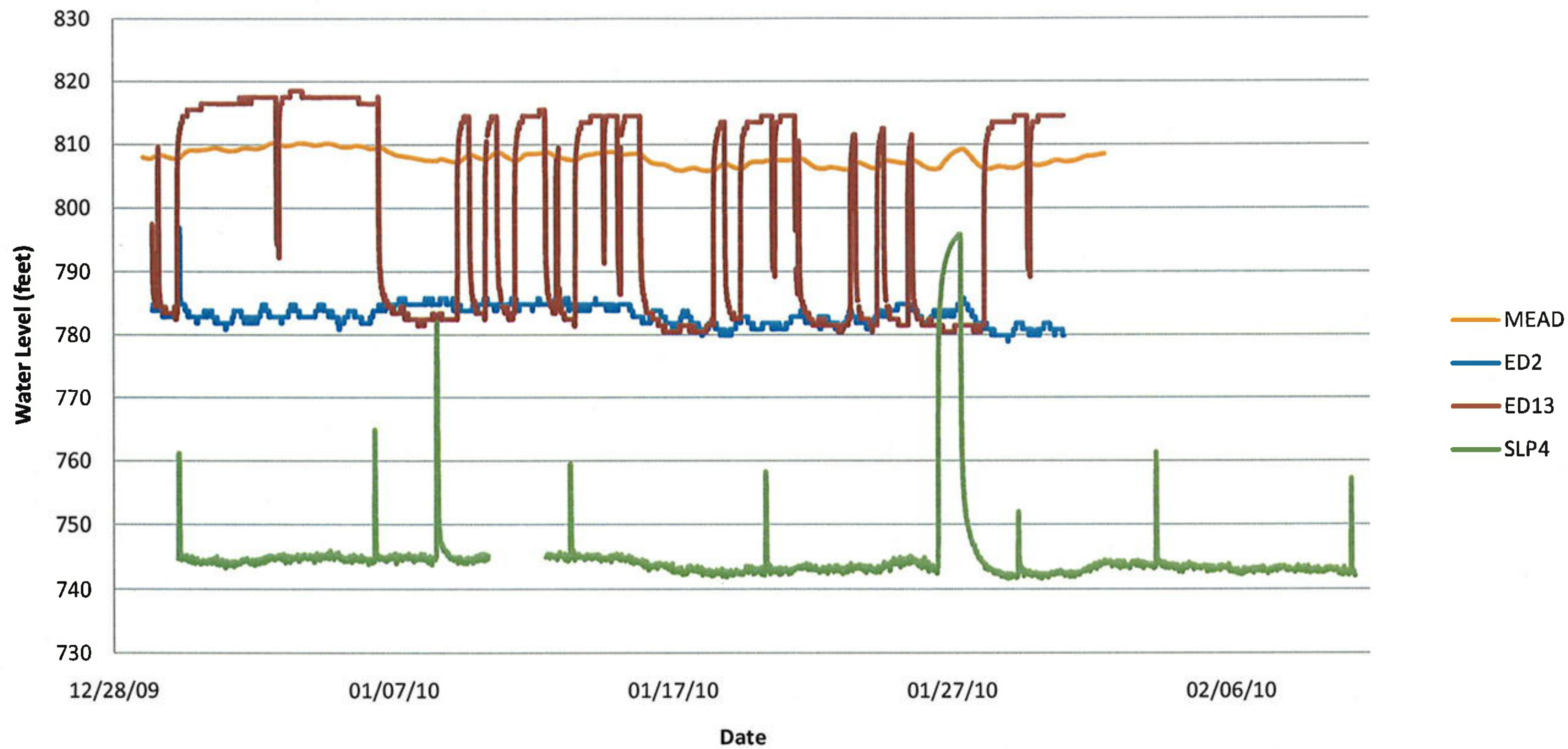


Figure 6B. Groundwater Levels in Meadowbrook Well and in Nearby Municipal Wells
St. Louis Park / Edina - January 2010
AECOM Project No. 60137283 / 60145589



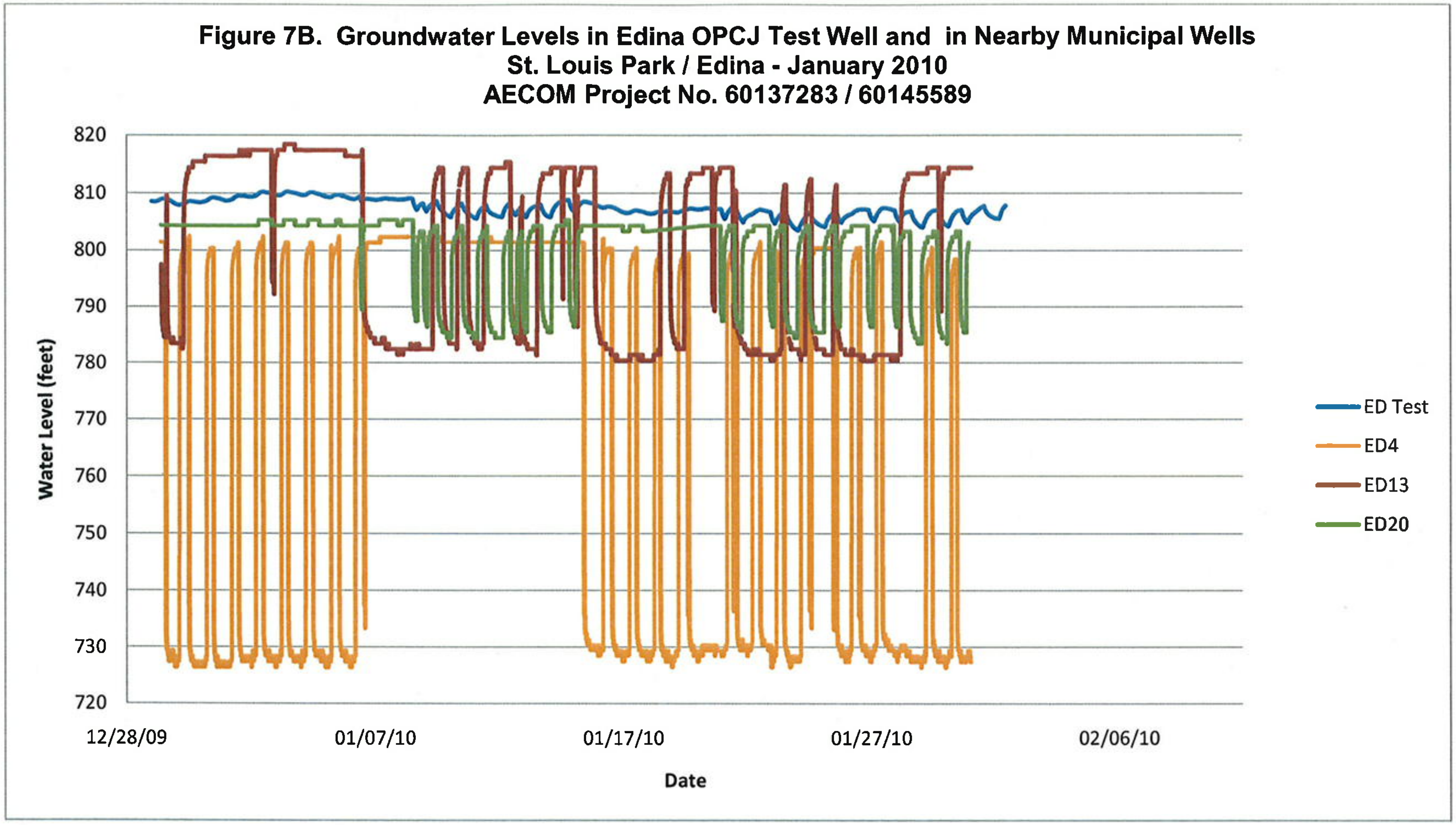


Figure 7B. Groundwater Levels in Edina OPCJ Test Well and in Nearby Municipal Wells
St. Louis Park / Edina - January 2010
AECOM Project No. 60137283 / 60145589
820
810
800
790
780
770
760
750
740
730
720
Water Level (feet)
12/28/09
01/07/10
01/17/10
01/27/10
02/06/10
Date
ED Test
ED4
ED13
ED20

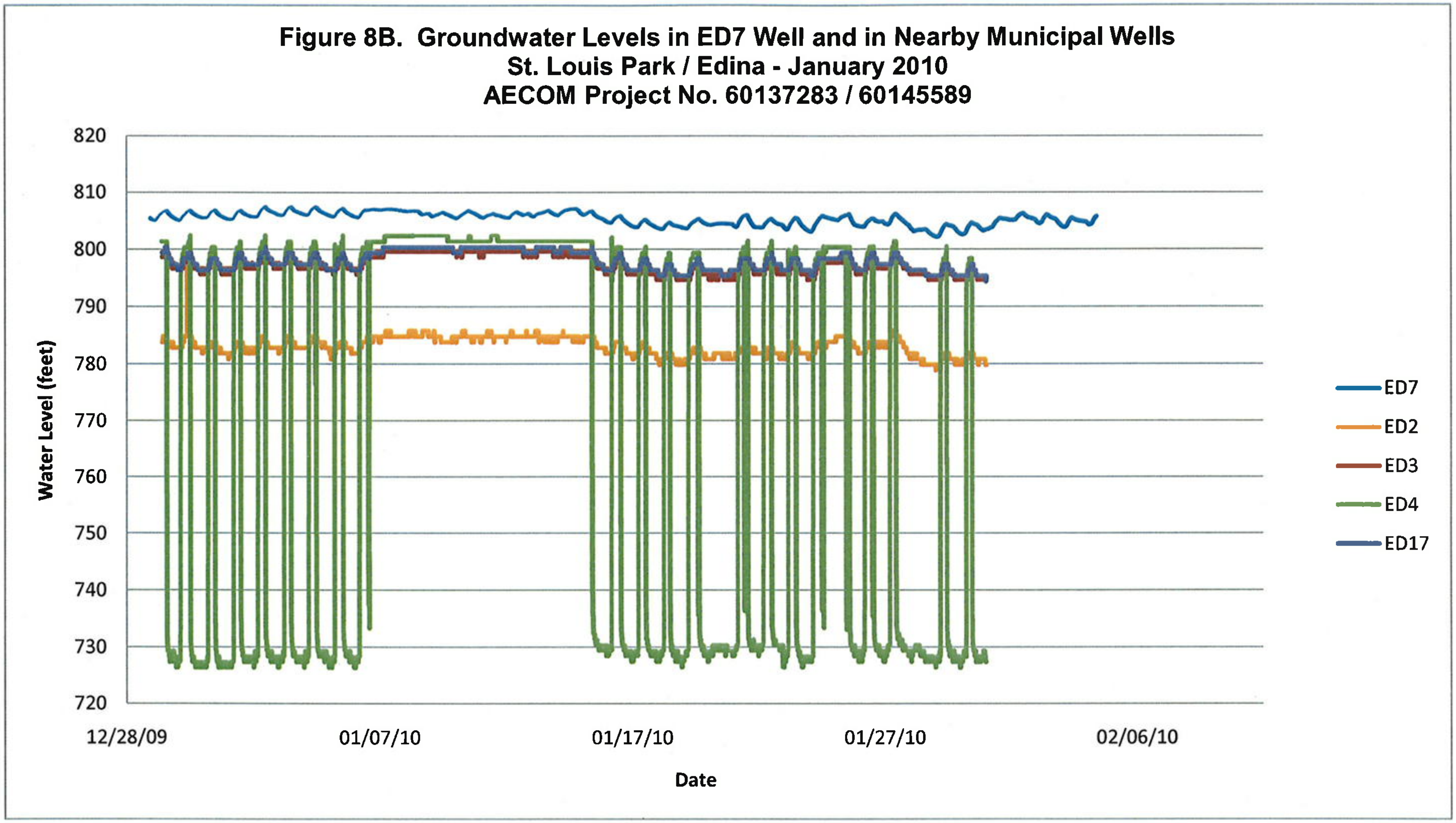


Figure 8B. Groundwater Levels in ED7 Well and in Nearby Municipal Wells
St. Louis Park / Edina - January 2010
AECOM Project No. 60137283 / 60145589
820
810
800
790
780
770
760
750
740
730
720
Water Level (feet)
12/28/09
01/07/10
01/17/10
01/27/10
02/06/10
Date
ED7
ED2
ED3
ED4
ED17

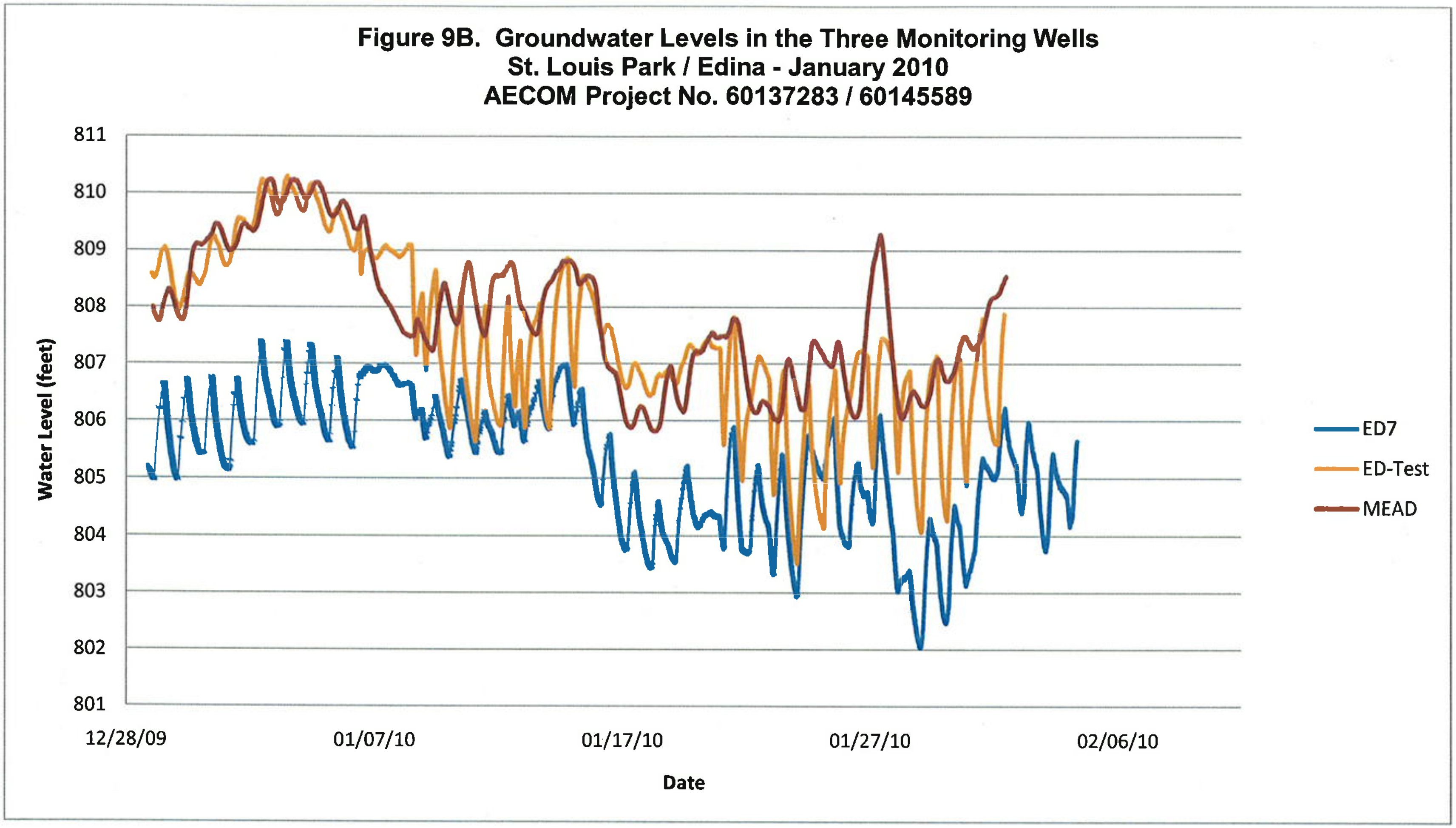


Figure 9B. Groundwater Levels in the Three Monitoring Wells
St. Louis Park / Edina - January 2010
AECOM Project No. 60137283 / 60145589
811
810
809
808
807
806
805
804
803
802
801
Water Level (feet)
12/28/09
01/07/10
01/17/10
01/27/10
02/06/10
Date
ED7
ED-Test
MEAD

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